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## Description

### Title of Invention

### EXPOSURE APPARATUS AND DEVICE MANUFACTURING METHOD

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### Technical Field

The present invention relates to exposure apparatuses and device manufacturing methods, and more particularly to an exposure apparatus that exposes an object with an energy  
10 beam via an optical system, and a device manufacturing method that uses the exposure apparatus.

### Background Art

Conventionally, in a lithography process for  
15 manufacturing electron devices (microdevices) such as semiconductor devices (integrated circuits or the like) or liquid crystal display elements, an exposure apparatus such as a projection exposure apparatus by a step-and-repeat method (a so-called stepper), or a projection exposure apparatus by  
20 a step-and-scan method (a so-called scanning stepper (which is also called a scanner)) is mainly used.

In this type of the projection exposure apparatus, a stage device that accurately drives a stage that moves along a predetermined two-dimensional plane while holding a wafer  
25 is provided, in order to overlay and form device patterns on a substrate such as a wafer or a glass plate (hereinafter, generically referred to as a wafer). In this case, in order to improve the throughput, it is required for the stage device to drive the stage at high speed with high acceleration.

Therefore, for example, as disclosed in Patent Literature 1, a stage device has been developed that has a configuration of driving a stage using a planar motor by an electromagnetic force drive method. Incidentally, the planar motor is  
5 configured of a stator arranged in a surface plate that holds the stage and a mover arranged in the stage.

Furthermore, it is required for the stage device to position a wafer with respect to the device patterns with high precision by driving the stage such that device patterns are overlaid and formed with high precision. Therefore, in order  
10 to respond to such requirement, for example, in the fifth embodiment of Patent Literature 2, a two-dimensional encoder system is enclosed that measures positional information of a stage by irradiating a grating arranged at the stage with  
15 a measurement beam from directly below and receiving reflected / diffracted light from the grating. In the two-dimensional encoder system related to the fifth embodiment of Patent Literature 2, a two-dimensional encoder (a head section that emits the measurement beam) is fixed to a surface plate that  
20 supports the stage. Therefore, if the two-dimensional encoder system described in Patent Literature 2 is applied to the previously-described stage device (Patent Literature 1) having a configuration that uses the planar motor without any changes, a reaction force accompanying a drive force used  
25 to drive the stage causes vibration of the surface plate at which the two-dimensional encoder (head section) is arranged, thereby the measurement accuracy of the two-dimensional encoder system is degraded, and as a consequence, there is a risk that the position control accuracy is degraded.

**Citation List****Patent Literature**

[PTL 1] U.S. Patent No. 6,437,463

[PTL 2] U.S. Patent Application Publication No.

5 2008/0094594

**Summary of Invention**

According to a first aspect of the present invention, there is provided a first exposure apparatus that exposes an object with an energy beam via an optical system and a liquid, the apparatus comprising: a first and a second movable bodies which independently move on a guide surface parallel to a two-dimensional plane while each holding the object, and at each of which a measurement surface parallel to the

10 two-dimensional plane is arranged; a guide surface forming member that forms the guide surface; a liquid supply device that supplies the liquid to a space between the optical system and the object held by the first or second movable body; a first measurement system that irradiates the measurement

15 surface of the first or second movable body that moves within a first area, with a measurement beam from a side opposite to the optical system with respect to the guide surface forming member, and receives light from the measurement surface, thereby obtaining positional information of the first or

20 second movable body; and a second measurement system that, when one of the first and second movable bodies located within the first area moves in proximity to the other of the first and second movable bodies and thereby the liquid supplied on the one of the movable bodies moves onto the other of the

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movable bodies, obtains at least positional information of the other of the movable bodies.

With this apparatus, when the liquid supplied on one of the first and second movable bodies located in the first area  
5 is moved onto the other of the first and second movable bodies, the first measurement system obtains the positional information of the one of the movable bodies with high precision and the second measurement system obtains at least the positional information of the other of the movable bodies  
10 with high precision. Consequently, by moving the first and second movable bodies in proximity to each other based on theses measurement results, the liquid supplied on the one of the movable bodies can be moved onto the other of the movable bodies.

15 In this case, the guide surface is used to guide the movable body in a direction orthogonal to the two-dimensional plane and can be of a contact type or a noncontact type. For example, the guide method of the noncontact type includes a configuration using static gas bearings such as air pads, a  
20 configuration using magnetic levitation, and the like.

Further, the guide surface is not limited to a configuration in which the movable body is guided following the shape of the guide surface. For example, in the configuration using static gas bearings such as air pads described above, the  
25 opposed surface of the guide surface forming member that is opposed to the movable body is finished so as to have a high flatness degree and the movable body is guided in a noncontact manner via a predetermined gap so as to follow the shape of the opposed surface. On the other hand, in the configuration

in which while a part of a motor or the like that uses an electromagnetic force is placed at the guide surface forming member, a part of the motor or the like is also placed at the movable body, and a force acting in a direction orthogonal to the two-dimensional plane described above is generated by the guide surface forming member and the movable body cooperating, the position of the movable body is controlled, by the force, on a predetermined two-dimensional plane. For example, a configuration is also included in which a planar motor is arranged at the guide surface forming member and forces in directions which include two directions orthogonal to each other within the two-dimensional plane and a direction orthogonal to the two-dimensional plane are generated on the movable body and the movable body is levitated in a noncontact manner without arranging the static gas bearings described above.

According to a second aspect of the present invention, there is provided a second exposure apparatus that exposes an object with an energy beam via an optical system, the apparatus comprising: a first and a second movable bodies which independently move on a guide surface parallel to a two-dimensional plane while each holding the object, and at each of which a measurement surface parallel to the two-dimensional plane is arranged; a guide surface forming member that forms the guide surface; a first measurement system that irradiates the measurement surface of the first or second movable body that moves within a first area, with a measurement beam from a side opposite to the optical system with respect to the guide surface forming member, and receives light from

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the measurement surface, thereby obtaining positional information of the first or second movable body; a mark detecting system that detects a plurality of marks formed on the object held by the first or second movable body within  
5 a second area that is away from the first area; a second measurement system that obtains positional information of the first and second movable bodies that move within a third area that includes an area between the first and second areas; and a third measurement system that irradiates the measurement  
10 surface of the first or second movable body that moves within the second area, with a measurement beam from a side opposite to the optical system with respect to the guide surface forming member, and receives light from the measurement surface, thereby obtaining positional information of the first or  
15 second movable body.

With this apparatus, it is possible to make the first and second movable bodies move between the first and second areas passing through the third area, using the positional information obtained by the first to third measurement  
20 systems.

According to a third aspect of the present invention, there is provided a third exposure apparatus that exposes an object with an energy beam via an optical system and a liquid, the apparatus comprising: a first and a second movable bodies  
25 each of which includes a first movable body member that is movable on a guide surface parallel to a two-dimensional plane while holding the object, and a second movable body member that is placed on an outer side of the first movable body member, supports the first movable body member relatively movable,



is movable on the guide surface, and has a measurement surface parallel to the two-dimensional plane arranged thereon; a liquid supply device that supplies the liquid to a space between the optical system and the object held by the first or second movable body; a first measurement system that  
5 irradiates the measurement surface of the first or second movable body that moves within a first area, with a measurement beam from a side opposite to the optical system, and receives light from the measurement surface, thereby obtaining  
10 positional information of the first or second movable body; and a second measurement system that, when the liquid supplied on one of the first and second movable bodies located within the first area is moved onto the other of the first and second movable bodies, obtains at least positional information of  
15 the other of the movable bodies.

With this apparatus, when the liquid supplied on one of the first and second movable bodies located within the first area is moved onto the other of the first and second movable bodies, the first measurement system obtains the positional  
20 information of the one of the movable bodies that moves within the first area and the second measurement system obtains at least the positional information of the other of the movable bodies with. Therefore, the liquid supplied on the one of the movable bodies can be moved onto the other of the movable bodies  
25 while the positional information of both the first and second movable bodies is obtained.

According to a fourth aspect of the present invention, there is provided a fourth exposure apparatus that exposes an object with an energy beam via an optical system and a liquid,

the apparatus comprising: a first and a second movable bodies each of which includes a first movable body member that is movable on a guide surface parallel to a two-dimensional plane while holding the object, and a second movable body member  
5 that is placed on an outer side of the first movable body member, supports the first movable body member relatively movable, and is movable on the guide surface; a liquid supply device that supplies the liquid to a space between the optical system and the object held by the first or second movable body; and  
10 a control system that moves the liquid supplied on one of the movable bodies onto the other of the movable bodies by driving the first and second movable bodies to cause the first and second movable body members, which the first and second movable bodies each have, to be in proximity in one axial direction  
15 within the two-dimensional plane and also cause the second movable body member of the first movable body and the second movable body member of the second movable body to be in proximity, and moving the first and second movable bodies in the one axial direction while maintaining the proximity state.

20 With this apparatus, the control system causes the first and second movable body members, which each of the first and second movable bodies has, to be in proximity in the one axial direction within the two-dimensional plane and also causes the second movable body member of the first movable body and  
25 the second movable body member of the second movable body to be in proximity by driving the first and second movable bodies, and moves the first and second movable bodies in the one axial direction while maintaining the proximity state, thereby moving the liquid supplied on one of the movable bodies onto

the other of the movable bodies. Therefore the liquid supplied on one of the first and second movable bodies can be moved onto the other.

According to a fifth aspect of the present invention, there is provided a device manufacturing method, comprising: exposing an object using any one of the first to fourth exposure apparatuses of the present invention; and developing the exposed object.

## 10 **Brief Description of Drawings**

FIG. 1 is a view schematically showing a configuration of an exposure apparatus of a first embodiment.

FIG. 2 is a plan view of the exposure apparatus of Fig. 1.

15 FIG. 3 is a side view of the exposure apparatus of Fig. 1 when viewed from the +Y side.

Fig. 4(A) is a plan view of a wafer stage which the exposure apparatus of Fig. 1 is equipped with, Fig. 4(B) is an end view of the cross section taken along the line B-B of Fig. 4(A), and Fig. 4(C) is an end view of the cross section taken along the line C-C of Fig. 4(A).

FIG. 5 is a view showing a configuration of a fine movement stage position measuring system.

FIG. 6 is a block diagram used to explain input/output relations of a main controller which the exposure apparatus of Fig. 1 is equipped with.

FIG. 7 is a view (No. 1) used to explain the procedure to expose a wafer using two wafer stages in the exposure apparatus of Fig. 1.

FIG. 8 is a view (No. 2) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of Fig. 1.

FIG. 9 is a view (No. 3) used to explain the procedure  
5 to expose a wafer using the two wafer stages in the exposure apparatus of Fig. 1.

FIG. 10 is a view (No. 4) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of Fig. 1.

10 FIG. 11 is a view (No. 5) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of Fig. 1.

FIG. 12 is a view (No. 6) used to explain the procedure to expose a wafer using the two wafer stages in the exposure  
15 apparatus of Fig. 1.

FIG. 13 is a view (No. 7) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of Fig. 1.

FIG. 14 is a view used to explain an example of a modified  
20 configuration of a wafer stage and the movement procedure of a liquid immersion area  $L_q$  between two wafer stages.

FIG. 15 is a plan view of an exposure apparatus of a second embodiment.

Fig. 16(A) is a plan view of a wafer stage which the  
25 exposure apparatus of the second embodiment is equipped with, and Fig. 16(B) is an end view of a cross section taken along the B-B line in Fig. 16(A).

FIG. 17 is a view showing a configuration of a stage position measuring system.

FIG. 18 is a block diagram showing a configuration of a control system of the exposure apparatus of the second embodiment.

FIG. 19 is a view (No. 1) used to explain the procedure to expose a wafer using two wafer stages in the exposure apparatus of the second embodiment.

FIG. 20 is a view (No. 2) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of the second embodiment.

FIG. 21 is a view (No. 3) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of the second embodiment.

FIG. 22 is a view (No. 4) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of the second embodiment.

FIG. 23 is a view (No. 5) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of the second embodiment.

FIG. 24 is a view (No. 6) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of the second embodiment.

FIG. 25 is a view (No. 7) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of the second embodiment.

FIG. 26 is a view (No. 8) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of the second embodiment.

FIG. 27 is a view (No. 9) used to explain the procedure to expose a wafer using the two wafer stages in the exposure

apparatus of the second embodiment.

FIG. 28 is a view (No. 10) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of the second embodiment.

5        FIG. 29 is a view (No. 11) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of the second embodiment.

FIG. 30 is a view (No. 12) used to explain the procedure to expose a wafer using the two wafer stages in the exposure  
10    apparatus of the second embodiment.

FIG. 31 is a view (No. 13) used to explain the procedure to expose a wafer using the two wafer stages in the exposure apparatus of the second embodiment.

FIG. 32 is a view (No. 14) used to explain the procedure  
15    to expose a wafer using the two wafer stages in the exposure apparatus of the second embodiment.

## **Description of Embodiments**

### **- First Embodiment**

20        A first embodiment of the present invention is described below, with reference to Figs. 1 to 13.

Fig. 1 schematically shows a configuration of an exposure apparatus 100 related to the first embodiment. Exposure apparatus 100 is a projection exposure apparatus by  
25    a step-and-scan method, which is a so-called scanner. As described later on, a projection optical system PL is provided in the embodiment, and in the description below, the explanation is given assuming that a direction parallel to an optical axis AX of projection optical system PL is a Z-axis

direction, a direction in which a reticle and a wafer are relatively scanned within a plane orthogonal to the Z-axis direction is a Y-axis direction, and a direction orthogonal to the Z-axis and the Y-axis is an X-axis direction, and rotational (tilt) directions around the X-axis, Y-axis and Z-axis are  $\theta_x$ ,  $\theta_y$  and  $\theta_z$  directions, respectively.

As shown in Fig. 1, exposure apparatus 100 is equipped with an exposure station (exposure processing area) 200 placed in the vicinity of the +Y side end on a base board 12, a measurement station (measurement processing area) 300 placed in the vicinity of the -Y side end on base board 12, a stage device 50 that includes two wafer stages WST1 and WST2, their control system and the like. In Fig. 1, wafer stage WST1 is located in exposure station 200 and a wafer W is held on wafer stage WST1. And, wafer stage WST2 is located in measurement station 300 and another wafer W is held on wafer stage WST2.

Exposure station 200 is equipped with an illuminations system 10, a reticle stage RST, a projection unit PU, a local liquid immersion device 8, and the like.

Illumination system 10 includes: a light source; and an illumination optical system that has an illuminance uniformity optical system including an optical integrator and the like, and a reticle blind and the like (none of which are illustrated), as disclosed in, for example, U.S. Patent Application Publication No. 2003/0025890 and the like. Illumination system 10 illuminates a slit-shaped illumination area IAR, which is defined by the reticle blind (which is also referred to as a masking system), on reticle R with illumination light (exposure light) IL with substantially

uniform illuminance. As illumination light IL, ArF excimer laser light (wavelength: 193nm) is used as an example.

On reticle stage RST, reticle R having a pattern surface (the lower surface in Fig. 1) on which a circuit pattern and the like are formed is fixed by, for example, vacuum adsorption. Reticle stage RST can be driven with a predetermined stroke at a predetermined scanning speed in a scanning direction (which is the Y-axis direction being a lateral direction of the page surface of Fig. 1) and can also be finely driven in the X-axis direction, with a reticle stage driving system (not illustrated in Fig. 1, see Fig. 6) including, for example, a linear motor or the like.

Positional information within the XY plane (including rotational information in the  $\theta_z$  direction) of reticle stage RST is constantly detected at a resolution of, for example, around 0.25 nm with a reticle laser interferometer (hereinafter, referred to as a "reticle interferometer") via a movable mirror 15 fixed to reticle stage RST (actually, a Y movable mirror (or a retroreflector) that has a reflection surface orthogonal to the Y-axis direction and an X movable mirror that has a reflection surface orthogonal to the X-axis direction are arranged). The measurement values of reticle interferometer 13 are sent to a main controller 20 (not illustrated in Fig. 1, see Fig. 6). Incidentally, as disclosed in, for example, PCT International Publication No. 2007/083758 (the corresponding U.S. Patent Application Publication No. 2007/0288121) and the like, the positional information of reticle stage RST can be measured by an encoder system.



Above reticle stage RST, a pair of reticle alignment systems  $RA_1$  and  $RA_2$  by an image processing method, each of which has an imaging device such as a CCD and uses light with an exposure wavelength (illumination light IL in the embodiment) as alignment illumination light, are placed (in Fig. 1, reticle alignment system  $RA_2$  hides behind reticle alignment system  $RA_1$  in the depth of the page surface), as disclosed in detail in, for example, U.S. Patent No. 5,646,413 and the like. Main controller 20 detects projected images of a pair of reticle alignment marks (the illustration is omitted) formed on reticle R and a pair of first fiducial marks on a measurement plate, which is described later, on fine movement stage WFS1 (or WFS2), that correspond to the reticle alignment marks via projection optical system PL in a state where the measurement plate is located directly under projection optical system PL, and the pair of reticle alignment systems  $RA_1$  and  $RA_2$  are used to detect a positional relation between the center of a projection area of a pattern of reticle R by projection optical system PL and a fiducial position on the measurement plate, i.e., the center of the pair of the first fiducial marks, according to such detection performed by main controller 20. The detection signals of reticle alignment systems  $RA_1$  and  $RA_2$  are supplied to main controller 20 (see Fig. 6) via a signal processing system that is not illustrated. Incidentally, reticle alignment systems  $RA_1$  and  $RA_2$  do not have to be arranged. In such a case, it is preferable that a detection system that has a light-transmitting section (photodetection section) arranged at a fine movement stage, which is described later on, is installed so as to detect projected images of the reticle

alignment marks, as disclosed in, for example, U.S. Patent Application Publication No. 2002/0041377 and the like.

Projection unit PU is placed below reticle stage RST in Fig. 1. Projection unit PU is supported, via a flange section FLG that is fixed to the outer periphery of projection unit PU, by a main frame (which is also referred to as a metrology frame) BD that is horizontally supported by a support member that is not illustrated. Main frame BD can be configured such that vibration from the outside is not transmitted to the main frame or the main frame does not transmit vibration to the outside, by arranging a vibration isolating device or the like at the support member. Projection unit PU includes a barrel 40 and projection optical system PL held within barrel 40. As projection optical system PL, for example, a dioptric system that is composed of a plurality of optical elements (lens elements) that are disposed along optical axis AX parallel to the Z-axis direction is used. Projection optical system PL is, for example, both-side telecentric and has a predetermined projection magnification (e.g. one-quarter, one-fifth, one-eighth times, or the like). Therefore, when illumination area IAR on reticle R is illuminated with illumination light IL from illumination system 10, illumination light IL passes through reticle R whose pattern surface is placed substantially coincident with a first plane (object plane) of projection optical system PL. Then, a reduced image of a circuit pattern (a reduced image of a part of a circuit pattern) of reticle R within illumination area IAR is formed in an area (hereinafter, also referred to as an exposure area) IA that is conjugate to illumination area

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IAR described above on wafer W, which is placed on the second plane (image plane) side of projection optical system PL and whose surface is coated with a resist (sensitive agent), via projection optical system PL (projection unit PU). Then, by  
5 moving reticle R relative to illumination area IAR (illumination light IL) in the scanning direction (Y-axis direction) and also moving wafer W relative to exposure area IA (illumination light IL) in the scanning direction (Y-axis direction) by synchronous drive of reticle stage RST and wafer  
10 stage WST1 (or WST2), scanning exposure of one shot area (divided area) on wafer W is performed. Accordingly, a pattern of reticle R is transferred onto the shot area. More specifically, in the embodiment, a pattern of reticle R is generated on wafer W by illumination system 10 and projection  
15 optical system PL, and the pattern is formed on wafer W by exposure of a sensitive layer (resist layer) on wafer W with illumination light IL. In this case, projection unit PU is held by main frame BD, and in the embodiment, main frame BD is substantially horizontally supported by a plurality (e.g.  
20 three or four) of support members placed on an installation surface (such as a floor surface) each via a vibration isolating mechanism. Incidentally, the vibration isolating mechanism can be placed between each of the support members and main frame BD. Further, as disclosed in, for example, PCT  
25 International Publication No. 2006/038952, main frame BD (projection unit PU) can be supported in a suspended manner by a main frame member (not illustrated) placed above projection unit PU or a reticle base or the like.

Local liquid immersion device 8 includes a liquid supply

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device 5, a liquid recovery device 6 (none of which are illustrated in Fig. 1, see Fig. 6), and a nozzle unit 32 and the like. As shown in Fig. 1, nozzle unit 32 is supported in a suspended manner by main frame BD that supports projection unit PU and the like, via a support member that is not illustrated, so as to enclose the periphery of the lower end of barrel 40 that holds an optical element closest to the image plane side (wafer W side) that configures projection optical system PL, which is a lens (hereinafter, also referred to as a "tip lens") 191 in this case. Nozzle unit 32 is equipped with a supply opening and a recovery opening of a liquid Lq, a lower surface to which wafer W is placed so as to be opposed and at which the recovery opening is arranged, and a supply flow channel and a recovery flow channel that are respectively connected to a liquid supply pipe 31A and a liquid recovery pipe 31B (none of which are illustrated in Fig. 1, see Fig. 2). One end of a supply pipe (not illustrated) is connected to liquid supply pipe 31A, while the other end of the supply pipe is connected to liquid supply device 5, and one end of a recovery pipe (not illustrated) is connected to liquid recovery pipe 31B, while the other end of the recovery pipe is connected to liquid recovery device 6.

In the embodiment, main controller 20 controls liquid supply device 5 (see Fig. 6) to supply the liquid to the space between tip lens 191 and wafer W and also controls liquid recovery device 6 (see Fig. 6) to recover the liquid from the space between tip lens 191 and wafer W. On this operation, main controller 20 controls the quantity of the supplied liquid and the quantity of the recovered liquid in order to hold a

constant quantity of liquid Lq (see Fig. 1) while constantly replacing the liquid in the space between tip lens 191 and wafer W. In the embodiment, as the liquid described above, a pure water (with a refractive index  $n \approx 1.44$ ) that transmits the ArF excimer laser light (the light with a wavelength of 193 nm) is to be used.

Measurement station 300 is equipped with an alignment device 99 arranged at main frame BD. Alignment device 99 includes five alignment systems AL1 and AL2<sub>1</sub> to AL2<sub>4</sub> shown in Fig. 2, as disclosed in, for example, U.S. Patent Application Publication No. 2008/0088843 and the like. To be more specific, as shown in Fig. 2, a primary alignment system AL1 is placed in a state where its detection center is located at a position a predetermined distance apart on the -Y side from optical axis AX, on a straight line (hereinafter, referred to as a reference axis) LV that passes through the center of projection unit PU (which is optical axis AX of projection optical system PL, and in the embodiment, which also coincides with the center of exposure area IA described previously) and is parallel to the Y-axis. On one side and the other side in the X-axis direction with primary alignment system AL1 in between, secondary alignment systems AL2<sub>1</sub> and AL2<sub>2</sub>, and AL2<sub>3</sub> and AL2<sub>4</sub>, whose detection centers are substantially symmetrically placed with respect to reference axis LV, are arranged respectively. More specifically, the detection centers of the five alignment systems AL1 and AL2<sub>1</sub> to AL2<sub>4</sub> are placed along a straight line (hereinafter, referred to as a reference axis) La that vertically intersects reference axis LV at the detection center of primary alignment system AL1

and is parallel to the X-axis. Note that a configuration including the five alignment systems AL1 and AL2<sub>1</sub> to AL2<sub>4</sub> and a holding device (slider) that holds these alignment systems is shown as alignment device 99 in Fig. 1. As disclosed in, 5 for example, U.S. Patent Application Publication No. 2009/0233234 and the like, secondary alignment systems AL2<sub>1</sub> to AL2<sub>4</sub> are fixed to the lower surface of main frame BD via the movable slider (see Fig. 1), and the relative positions of the detection areas of the secondary alignment systems are 10 adjustable at least in the X-axis direction with a drive mechanism that is not illustrated.

In the embodiment, as each of alignment systems AL1 and AL2<sub>1</sub> to AL2<sub>4</sub>, for example, an FIA (Field Image Alignment) system by an image processing method is used. The configurations of 15 alignment systems AL1 and AL2<sub>1</sub> to AL2<sub>4</sub> are disclosed in detail in, for example, PCT International Publication No. 2008/056735 and the like. The imaging signal from each of alignment systems AL1 and AL2<sub>1</sub> to AL2<sub>4</sub> is supplied to main controller 20 (see Fig. 6) via a signal processing system that 20 is not illustrated.

Note that exposure apparatus 100 has a first loading position where a carriage operation of a wafer is performed with respect to wafer stage WST1 and a second loading position where a carriage operation of a wafer is performed with respect 25 to wafer stage WST2, although the loading positions are not illustrated. In the case of the embodiment, the first loading position is arranged on the surface plate 14A side and the second loading position is arranged on the surface plate 14B side.

As shown in Fig. 1, stage device 50 is equipped with base board 12, a pair of surface plates 14A and 14B placed above base board 12 (in Fig. 1, surface plate 14B hides behind surface plate 14 in the depth of the page surface), the two wafer stages  
5 WST1 and WST2 that move on a guide surface parallel to the XY plane that is formed by the upper surfaces of the pair of surface plates 14A and 14B, tube carriers TCa and TCb (tube carrier TCb is not illustrated in Fig. 1, see the drawings such as Figs. 2 and 3) that are respectively connected to wafer  
10 stages WST1 and WST2 via piping/wiring systems (hereinafter, referred to as tubes for the sake of convenience) Ta<sub>2</sub> and Tb<sub>2</sub> (not illustrated in Fig. 1, see Figs. 2 and 3), a measurement system that measures positional information of wafer stages WST1 and WST2, and the like. The electric power for various  
15 types of sensors and actuators such as motors, the coolant for temperature adjustment to the actuators, the pressurized air for air bearings, and the like are supplied from the outside to wafer stages WST1 and WST2 via tubes Ta<sub>2</sub> and Tb<sub>2</sub>, respectively. Note that, in the description below, the  
20 electric power, the coolant for temperature adjustment, the pressurized air and the like are also referred to as the power usage collectively. In the case where a vacuum suction force is necessary, the force for vacuum (negative pressure) is also included in the power usage.

25 Base board 12 is made up of a member having a tabular outer shape, and as shown in Fig. 1, is substantially horizontally (parallel to the XY plane) supported via a vibration isolating mechanism (the illustration is omitted) on a floor surface 102. In the center portion in the X-axis

direction of the upper surface of base board 12, a recessed section 12a (recessed groove) extending in a direction parallel to the Y-axis is formed, as shown in Fig. 3. On the upper surface side of base board 12 (excluding a portion where  
5 recessed section 12a is formed, in this case), a coil unit (the illustration is omitted) is housed that includes a plurality of coils placed in a matrix shape with the XY two-dimensional directions serving as a row direction and a column direction.

10 As shown in Fig. 2, surface plates 14A and 14B are each made up of a rectangular plate-shaped member whose longitudinal direction is in the Y-axis direction in a planar view (when viewed from above) and are respectively placed on the -X side and the +X side of reference axis LV. Surface plate  
15 14A and surface plate 14B are placed with a very narrow gap in between in the X-axis direction, symmetric with respect to reference axis LV. By finishing the upper surface (the +Z side surface) of each of surface plates 14A and 14B such that the upper surface has a very high flatness degree, it is  
20 possible to make the upper surfaces function as a guide surface with respect to the Z-axis direction used when each of wafer stages WST1 and WST2 moves following the XY plane. Alternatively, a configuration can be employed in which a force in the Z direction is made to act on wafer stages WST1 and  
25 WST2 by planar motors, which are described later on, to magnetically levitate wafer stages WST1 and WST2 above surface plates 14A and 14B. In the case of the embodiment, the configuration that uses the planar motors is employed and static gas bearings are not used, and therefore, the flatness



degree of the upper surfaces of surface plates 14A and 14B does not have to be so high as in the above description.

As shown in Fig. 3, surface plates 14A and 14B are supported on upper surfaces 12b of both side portions of recessed section 12a of base board 12 via air bearings (or  
5 rolling bearings) that are not illustrated.

Surface plates 14A and 14B respectively have first sections 14A<sub>1</sub> and 14B<sub>1</sub> each having a relatively thin plate shape on the upper surface of which the guide surface is formed,  
10 and second sections 14A<sub>2</sub> and 14B<sub>2</sub> each having a relatively thick plate shape and being short in the X-axis direction that are integrally fixed to the lower surfaces of first sections 14A<sub>1</sub> and 14B<sub>1</sub>, respectively. The end on the +X side of first section 14A<sub>1</sub> of surface plate 14A slightly overhangs, to the +X side,  
15 the end surface on the +X side of second section 14A<sub>2</sub>, and the end on the -X side of first section 14B<sub>1</sub> of surface plate 14B slightly overhangs, to the -X side, the end surface on the -X side of second section 14B<sub>2</sub>. However, the configuration is not limited to the above-described one, and a configuration  
20 can be employed in which the overhangs are not arranged.

Inside each of first sections 14A<sub>1</sub> and 14B<sub>1</sub>, a coil unit (the illustration is omitted) is housed that includes a plurality of coils placed in a matrix shape with the XY two-dimensional directions serving as a row direction and a  
25 column direction. The magnitude and direction of the electric current supplied to each of the plurality of coils that configure each of the coil units are controlled by main controller 20 (see Fig. 6).

Inside (on the bottom portion of) second section 14A<sub>2</sub>

of surface plate 14A, a magnetic unit (the illustration is omitted), which is made up of a plurality of permanent magnets (and yokes that are not illustrated) placed in a matrix shape with the XY two-dimensional directions serving as a row  
5 direction and a column direction, is housed so as to correspond to the coil unit housed on the upper surface side of base board 12. The magnetic unit configures, together with the coil unit of base board 12, a surface plate driving system 60A (see Fig. 6) that is made up of a planar motor by the electromagnetic  
10 force (Lorentz force) drive method that is disclosed in, for example, U.S. Patent Application Publication No. 2003/0085676 and the like. Surface plate driving system 60A generates a drive force that drives surface plate 14A in directions of three degrees of freedom (X, Y,  $\theta_z$ ) within the XY plane.

15 Similarly, inside (on the bottom portion of) second section 14B<sub>2</sub> of surface plate 14B, a magnetic unit (the illustration is omitted) made up of a plurality of permanent magnets (and yokes that are not illustrated) is housed that configures, together with the coil unit of base board 12, a  
20 surface plate driving system 60B (see Fig. 6) made up of a planar motor that drives surface plate 14B in the directions of three degrees of freedom within the XY plane. Incidentally, the placement of the coil unit and the magnetic unit of the planar motor that configures each of surface plate driving  
25 systems 60A and 60B can be reverse (a moving coil type that has the magnetic unit on the base board side and the coil unit on the surface plate side) to the above-described case (a moving magnet type).

Positional information of surface plates 14A and 14B in

25.

the directions of three degrees of freedom is obtained (measured) independently from each other by a first surface plate position measuring system 69A and a second surface plate position measuring system 69B (see Fig. 6), respectively, which each include, for example, an encoder system. The output of each of first surface plate position measuring system 69A and second surface plate position measuring system 69B is supplied to main controller 20 (see Fig. 6), and main controller 20 controls the magnitude and direction of the electric current supplied to the respective coils that configure the coil units of surface plate driving systems 60A and 60B, using (based on) the outputs of surface plate position measuring systems 69A and 69B, thereby controlling the respective positions of surface plates 14A and 14B in the directions of three degrees of freedom within the XY plane, as needed. Main controller 20 drives surface plates 14A and 14B via surface plate driving systems 60A and 60B using (based on) the outputs of surface plate position measuring systems 69A and 69B to return surface plates 14A and 14B to the reference position of the surface plates such that the movement distance of surface plates 14A and 14B from the reference position falls within a predetermined range, when surface plates 14A and 14B function as counterbalances to be described later on. More specifically, surface plate driving systems 60A and 60B are used as trim motors.

While the configurations of first surface plate position measuring system 69A and second surface plate position measuring system 69B are not especially limited, an encoder system can be used in which, for example, encoder heads, which

obtain (measure) positional information of the respective surface plates 14A and 14B in the directions of three degrees of freedom within the XY plane by irradiating measurement beams on scales (e.g. two-dimensional gratings) placed on the lower surfaces of second sections 14A<sub>2</sub> and 14B<sub>2</sub> respectively and using reflected light (diffraction light from the two-dimensional gratings) obtained by the irradiation, are placed at base board 12 (or the encoder heads are placed at second sections 14A<sub>2</sub> and 14B<sub>2</sub> and scales are placed at base board 12, respectively). Incidentally, it is also possible to obtain (measure) the positional information of surface plates 14A and 14B by, for example, an optical interferometer system or a measurement system that is a combination of an optical interferometer system and an encoder system.

One of the wafer stages, wafer stage WST1 is equipped with a fine movement stage (which is also referred to as a table) WFS1 that holds wafer W and a coarse movement stage WCS1 having a rectangular frame shape that encloses the periphery of fine movement stage WFS1, as shown in Fig. 2. The other of the wafer stages, wafer stage WST2 is equipped with a fine movement stage WFS2 that holds wafer W and a coarse movement stage WCS2 having a rectangular frame shape that encloses the periphery of fine movement stage WFS2, as shown in Fig. 2. As is obvious from Fig. 2, wafer stage WST2 has completely the same configuration including the drive system, the position measuring system and the like, as wafer stage WST1 except that wafer stage WST2 is placed in a state laterally reversed with respect to wafer stage WST1. Consequently, in the description below, wafer stage WST1 is representatively

focused on and described, and wafer stage WST2 is described only in the case where such description is especially needed.

As shown in Fig. 4(A), coarse movement stage WCS1 has a pair of coarse movement slider sections 90a and 90b which are placed parallel to each other, spaced apart in the Y-axis direction, and each of which is made up of a rectangular parallelepiped member whose longitudinal direction is in the X-axis direction, and a pair of coupling members 92a and 92b each of which is made up of a rectangular parallelepiped member whose longitudinal direction is in the Y-axis direction, and which couple the pair of coarse movement slider sections 90a and 90b with one ends and the other ends thereof in the Y-axis direction. More specifically, coarse movement stage WCS1 is formed into a rectangular frame shape with a rectangular opening section, in its center portion, that penetrates in the Z-axis direction.

Inside (on the bottom portions of) coarse movement slider sections 90a and 90b, as shown in Figs. 4(B) and 4(C), magnetic units 96a and 96b are housed respectively. Magnetic units 96a and 96b correspond to the coil units housed inside first sections 14A<sub>1</sub> and 14B<sub>1</sub> of surface plates 14A and 14B, respectively, and are each made up of a plurality of magnets placed in a matrix shape with the XY two-dimensional directions serving as a row direction and a column direction. Magnetic units 96a and 96b configure, together with the coil units of surface plates 14A and 14B, a coarse movement stage driving system 62A (see Fig. 6) that is made up of a planar motor by the electromagnetic force (Lorentz force) drive method that is capable of generating drive forces in the directions of

six degrees of freedom to coarse movement stage WCS1, which is disclosed in, for example, U.S. Patent Application Publication No. 2003/0085676 and the like. Further, similar thereto, magnetic units, which coarse movement stage WCS2 (see Fig. 2) of wafer stage WST2 has, and the coil units of surface plates 14A and 14B configure a coarse movement stage driving system 62B (see Fig. 6) made up of a planar motor. In this case, since a force in the Z-axis direction acts on coarse movement stage WCS1 (or WCS2), the coarse movement stage is magnetically levitated above surface plates 14A and 14B. Therefore, it is not necessary to use static gas bearings for which relatively high machining accuracy is required, and thus it becomes unnecessary to increase the flatness degree of the upper surfaces of surface plates 14A and 14B.

Incidentally, while coarse movement stages WCS1 and WCS2 of the embodiment have the configuration in which only coarse movement slider sections 90a and 90b have the magnetic units of the planar motors, this is not intended to be limiting, and the magnetic unit can be placed also at coupling members 92a and 92b. Further, the actuators to drive coarse movement stages WCS1 and WCS2 are not limited to the planar motors by the electromagnetic force (Lorentz force) drive method, but for example, planar motors by a variable magnetoresistance drive method or the like can be used. Further, the drive directions of coarse movement stages WCS1 and WCS2 are not limited to the directions of six degrees of freedom, but can be, for example, only directions of three degrees of freedom (X, Y,  $\theta_z$ ) within the XY plane. In this case, coarse movement stages WCS1 and WCS2 should be levitated above surface plates.

14A and 14B, for example, using static gas bearings (e.g. air bearings). Further, in the embodiment, while the planar motor of a moving magnet type is used as each of coarse movement stage driving systems 62A and 62B, this is not intended to be limiting, and a planar motor of a moving coil type in which the magnetic unit is placed at the surface plate and the coil unit is placed at the coarse movement stage can also be used.

On the side surface on the -Y side of coarse movement slider section 90a and on the side surface on the +Y side of coarse movement slider section 90b, guide members 94a and 94b that function as a guide used when fine movement stage WFS1 is finely driven are respectively fixed. As shown in Fig. 4(B), guide member 94a is made up of a member having an L-like sectional shape arranged extending in the X-axis direction and its lower surface is placed flush with the lower surface of coarse movement slider section 90a. Guide member 94b is configured and placed similar to guide member 94a, although guide member 94b is bilaterally symmetric to guide member 94a.

Inside (on the bottom surface of) guide member 94a, a pair of coil units CUa and CUb, each of which includes a plurality of coils placed in a matrix shape with the XY two-dimensional directions serving as a row direction and a column direction, are housed at a predetermined distance in the X-axis direction (see Fig. 4(A)). Meanwhile, inside (on the bottom portion of) guide member 94b, one coil unit CUc, which includes a plurality of coils placed in a matrix shape with the XY two-dimensional directions serving as a row direction and a column direction, is housed (see Fig. 4(A)). The magnitude and direction of the electric current supplied

to each of the coils that configure coil units CUa to CUC are controlled by main controller 20 (see Fig. 6).

Coupling members 92a and 92b are formed to be hollow, and piping members, wiring members and the like, which are not illustrated, used to supply the power usage to fine movement stage WFS1 are housed inside. Inside coupling members 92a and/or 92b, various types of optical members (e.g. an aerial image measuring instrument, an uneven illuminance measuring instrument, an illuminance monitor, a wavefront aberration measuring instrument, and the like) can be housed.

In this case, when wafer stage WST1 is driven with acceleration / deceleration in the Y-axis direction on surface plate 14A, by the planar motor that configures coarse movement stage driving system 62A (e.g. when wafer stage WST1 moves between exposure station 200 and measurement station 300), surface plate 14A is driven in a direction opposite to wafer stage WST1 according to the so-called law of action and reaction (the law of conservation of momentum) owing to the action of a reaction force by the drive of wafer stage WST1. Further, it is also possible to make a state where the law of action and reaction described above does not hold, by generating a drive force in the Y-axis direction with surface plate driving system 60A.

Further, when wafer stage WST 2 is driven in the Y-axis direction on surface plate 14B, surface plate 14B is also driven in a direction opposite to wafer stage WST2 according to the so-called law of action and reaction (the law of conservation of momentum) owing to the action of a reaction force of a drive force of wafer stage WST2. More specifically,



surface plates 14A and 14B function as the counter masses and the momentum of a system composed of wafer stages WST1 and WST2 and surface plates 14A and 14B as a whole is conserved and movement of the center of gravity does not occur.

5 Consequently, any inconveniences do not arise such as the uneven loading acting on surface plates 14A and 14B owing to the movement of wafer stages WST1 and WST2 in the Y-axis direction. Incidentally, regarding wafer stage WST2 as well, it is possible to make a state where the law of action and  
10 reaction described above does not hold, by generating a drive force in the Y-axis direction with surface plate driving system 60B.

Further, by the action of a reaction force of a drive force in the X-axis direction of wafer stages WST1 and WST2,  
15 surface plates 14A and 14B function as the counter masses.

Further, the mirror polishing is applied to each of the side surface on the +Y side of coarse movement slider section 90a, the side surface on the -Y side of coarse movement slider 90b and the side surface on the -X side of coupling member  
20 92a, and reflection surfaces 17Y<sub>2</sub>, 17Y<sub>1</sub> and 17X are formed. These reflection surfaces are used in position measurement of wafer stages WST1 and WST2 by coarse movement stage position measuring systems 68A and 68B to be described later on. Incidentally, instead of reflection surfaces 17Y<sub>2</sub>, 17Y<sub>1</sub> and  
25 17X, a movable mirror composed of a planar mirror can be fixed to coarse movement slider sections 90a and 90b and coupling member 92a.

As shown in Figs. 4(A) and 4(B), fine movement stage WFS1 is equipped with a main section 80 made up of a member having

a rectangular shape in a planar view, a pair of fine movement slider sections 84a and 84b fixed to the side surface on the +Y side of main section 80, and a fine movement slider section 84c fixed to the side surface on the -Y side of main section  
5 80.

Main section 80 is formed by a material with a relatively small coefficient of thermal expansion, e.g., ceramics, glass or the like, and is supported by coarse movement stage WCS1 in a noncontact manner in a state where the bottom surface  
10 of the main section is located flush with the bottom surface of coarse movement stage WCS1. Main section 80 can be hollowed for reduction in weight. Incidentally, the bottom surface of main section 80 does not necessarily have to be flush with the bottom surface of coarse movement stage WCS1.

15 In the center of the upper surface of main section 80, a wafer holder (not illustrated) that holds wafer W by vacuum adsorption or the like is placed. In the embodiment, the wafer holder by a so-called pin chuck method is used in which a plurality of support sections (pin members) that support wafer  
20 W are formed, for example, within an annular protruding section (rim section), and the wafer holder, whose one surface (front surface) serves as a wafer mounting surface, has a two-dimensional grating RG to be described later and the like arranged on the other surface (back surface) side.

25 Incidentally, the wafer holder can be formed integrally with fine movement stage WFS1 (main section 80), or can be fixed to main section 80 so as to be detachable via, for example, a holding mechanism such as an electrostatic chuck mechanism or a clamp mechanism. In this case, grating RG is to be

arranged on the back surface side of main section 80. Further, the wafer holder can be fixed to main section 80 by an adhesive agent or the like. On the upper surface of main section 80, as shown in Fig. 4(A), a plate (liquid-repellent plate) 82, in the center of which a circular opening that is slightly larger than wafer W (wafer holder) is formed and which has a rectangular outer shape (contour) that corresponds to main section 80, is attached on the outer side of the wafer holder (mounting area of wafer W). The liquid-repellent treatment against liquid Lq is applied to the surface of plate 82 (the liquid-repellent surface is formed). In the embodiment, the surface of plate 82 includes a base material made up of metal, ceramics, glass or the like, and a film of liquid-repellent material formed on the surface of the base material. The liquid-repellent material includes, for example, PFA (Tetra fluoro ethylene-perfluoro alkylvinyl ether copolymer), PTFE (Poly tetra fluoro ethylene), Teflon (registered trademark) or the like. Incidentally, the material that forms the film can be an acrylic-type resin or a silicon-series resin. Further, the entire plate 82 can be formed with at least one of the PFA, PTFE, Teflon (registered trademark), acrylic-type resin and silicon-series resin. In the embodiment, the contact angle of the upper surface of plate 82 with respect to liquid Lq is, for example, more than or equal to 90 degrees. On the surface of coupling member 92b described previously as well, the similar liquid-repellent treatment is applied.

Plate 82 is fixed to the upper surface of main section 80 such that the entire surface (or a part of the surface) of plate 82 is flush with the surface of wafer W. Further,

the surfaces of plate 82 and wafer W are located substantially flush with the surface of coupling member 92b described previously. Further, in the vicinity of a corner on the +X side located on the +Y side of plate 82, a circular opening is formed, and a measurement plate FM1 is placed in the opening without any gap therebetween in a state substantially flush with the surface of wafer W. On the upper surface of measurement plate FM1, the pair of first fiducial marks to be respectively detected by the pair of reticle alignment systems RA<sub>1</sub> and RA<sub>2</sub> (see Figs. 1 and 6) described earlier and a second fiducial mark to be detected by primary alignment system AL1 (none of the marks are illustrated) are formed. In fine movement stage WFS2 of wafer stage WST2, as shown in Fig. 2, in the vicinity of a corner on the -X side located on the +Y side of plate 82, a measurement plate FM2 that is similar to measurement plate FM1 is fixed in a state substantially flush with the surface of wafer W. Incidentally, instead of attaching plate 82 to fine movement stage WFS1 (main section 80), it is also possible, for example, that the wafer holder is formed integrally with fine movement stage WFS1 and the liquid-repellent treatment is applied to the peripheral area, which encloses the wafer holder (the same area as plate 82 (which may include the surface of the measurement plate)), of the upper surface of fine movement stage WFS1 and the liquid repellent surface is formed.

In the center portion of the lower surface of main section 80 of fine movement stage WFS1, as shown in Fig. 4(B), a plate having a predetermined thin plate shape, which is large to the extent of covering the wafer holder (mounting area of

wafer W) and measurement plate FM1 (or measurement plate FM2 in fine movement stage WFS2), is placed in a state where its lower surface is located substantially flush with the other section (the peripheral section) (the lower surface of the plate does not protrude below the peripheral section). On one surface (the upper surface (or the lower surface)) of the plate, two-dimensional grating RG (hereinafter, simply referred to as grating RG) is formed. Grating RG includes a reflective diffraction grating (X diffraction grating) whose periodic direction is in the X-axis direction and a reflective diffraction grating (Y diffraction grating) whose periodic direction is in the Y-axis direction. The plate is formed by, for example, glass, and grating RG is created by graving the graduations of the diffraction gratings at a pitch, for example, between 138 nm to 4  $\mu\text{m}$ , e.g. at a pitch of 1  $\mu\text{m}$ . Incidentally, grating RG can also cover the entire lower surface of main section 80. Further, the type of the diffraction grating used for grating RG is not limited to the one on which grooves or the like are mechanically formed, but for example, a diffraction grating that is created by exposing interference fringes on a photosensitive resin can also be employed. Incidentally, the configuration of the plate having a thin plate shape is not necessarily limited to the above-described one.

As shown in Fig. 4(A), the pair of fine movement slider sections 84a and 84b are each a plate-shaped member having a roughly square shape in a planar view, and are placed apart at a predetermined distance in the X-axis direction, on the side surface on the +Y side of main section 80. Fine movement

slider section 84c is a plate-shaped member having a rectangular shape elongated in the X-axis direction in a planar view, and is fixed to the side surface on the -Y side of main section 80 in a state where one end and the other end in its longitudinal direction are located on straight lines parallel to the Y-axis that are substantially collinear with the centers of fine movement slider sections 84a and 84b.

The pair of fine movement slider sections 84a and 84b are respectively supported by guide member 94a described earlier, and fine movement slider section 84c is supported by guide member 94b. More specifically, fine movement stage WFS is supported at three noncollinear positions with respect to coarse movement stage WCS.

Inside fine movement slider sections 84a to 84c, magnetic units 98a, 98b and 98c, which are each made up of a plurality of permanent magnets (and yokes that are not illustrated) placed in a matrix shape with the XY two-dimensional directions serving as a row direction and a column direction, are housed, respectively, so as to correspond to coil units CUa to CUc that guide sections 94a and 94b of coarse movement stage WCS1 have. Magnetic unit 98a together with coil unit CUa, magnetic unit 98b together with coil unit CUb, and magnetic unit 98c together with coil unit CUc respectively configure three planar motors by the electromagnetic force (Lorentz force) drive method that are capable of generating drive forces in the X-axis, Y-axis and Z-axis directions, as disclosed in, for example, U.S. Patent Application Publication No. 2003/0085676 and the like, and these three planar motors configure a fine movement stage

driving system 64A (see Fig. 6) that drives fine movement stage WFS1 in directions of six degrees of freedom ( $X$ ,  $Y$ ,  $Z$ ,  $\theta_x$ ,  $\theta_y$  and  $\theta_z$ ).

In wafer stage WST2 as well, three planar motors composed  
5 of coil units that coarse movement stage WCS2 has and magnetic units that fine movement stage WFS2 has are configured likewise, and these three planar motors configure a fine movement stage driving system 64B (see Fig. 6) that drives fine movement stage WFS2 in directions of six degrees of freedom ( $X$ ,  $Y$ ,  $Z$ ,  $\theta_x$ ,  
10  $\theta_y$  and  $\theta_z$ ).

Fine movement stage WFS1 is movable in the  $X$ -axis direction, with a longer stroke compared with the directions of the other five degrees of freedom, along guide members 94a and 94b arranged extending in the  $X$ -axis direction. The same  
15 applies to fine movement stage WFS2.

With the configuration as described above, fine movement stage WFS1 is movable in the directions of six degrees of freedom with respect to coarse movement stage WCS1. Further, on this operation, the law of action and reaction (the law  
20 of conservation of momentum) that is similar to the previously described one holds owing to the action of a reaction force by drive of fine movement stage WFS1. More specifically, coarse movement stage WCS1 functions as the counter mass of fine movement stage WFS1, and coarse movement stage WCS1 is  
25 driven in a direction opposite to fine movement stage WFS1. Fine movement stage WFS2 and coarse movement stage WCS2 has the similar relation.

Note that, in the embodiment, when broadly driving fine movement stage WFS1 (or WFS2) with acceleration / deceleration

in the X-axis direction (e.g. in the cases such as when a stepping operation between shot areas is performed during exposure), main controller 20 drives fine movement stage WFS1 (or WFS2) in the X-axis direction by the planar motors that  
5 configure fine movement stage driving system 64A (or 64B). Further, along with this drive, main controller 20 gives the initial velocity, which drives coarse movement stage WCS1 (or WCS2) in the same direction as with fine movement stage WFS1 (or WFS2), to coarse movement stage WCS1 (or WCS2), via coarse  
10 movement stage driving system 62A (or 62B) (drives coarse movement stage WCS1 (or WCS2) in the same direction as with fine movement stage WCS1 (or WCS2)). This causes coarse movement stage WCS1 (or WCS2) to function as the so-called counter mass. Accordingly, it is possible to decrease a  
15 movement distance of coarse movement stage WCS1 (or WCS2) in the opposite direction that accompanies the movement of fine movement stage WFS1 (or WFS2) in the X-axis direction (that is caused by a reaction force of the drive force). Especially, in the case where fine movement stage WFS1 (or WFS2) performs  
20 an operation including the step movement in the X-axis direction, or more specifically, fine movement stage WFS1 (or WFS2) performs an operation of alternately repeating the acceleration and the deceleration in the X-axis direction, the stroke in the X-axis direction needed for the movement  
25 of coarse movement stage WCS1 (or WCS2) can be the shortest. On this operation, main controller 20 should give coarse movement stage WCS1 (or WCS2) the initial velocity with which the center of gravity of the entire system of wafer stage WST1 (or WST2) that includes the fine movement stage and the coarse



movement stage performs constant velocity motion in the X-axis direction. With this operation, coarse movement stage WCS1 (or WCS2) performs a back-and-forth motion within a predetermined range with the position of fine movement stage WFS1 (or WFS2) serving as a reference. Consequently, as the movement stroke of coarse movement stage WCS1 (or WCS2) in the X-axis direction, the distance that is obtained by adding some margin to the predetermined range should be prepared. Such details are disclosed in, for example, U.S. Patent Application Publication No. 2008/0143994 and the like.

Further, as described earlier, since fine movement stage WFS1 is supported at the three noncollinear positions by coarse movement stage WCS1, main controller 20 can tilt fine movement stage WFS1 (i.e. wafer W) at an arbitrary angle (rotational amount) in the  $\theta_x$  direction and/or the  $\theta_y$  direction with respect to the XY plane by, for example, appropriately controlling a drive force (thrust) in the Z-axis direction that is made to act on each of fine movement slider sections 84a to 84c. Further, main controller 20 can make the center portion of fine movement stage WFS1 bend in the +Z direction (into a convex shape), for example, by making a drive force in the + $\theta_x$  direction (a counterclockwise direction on the page surface of Fig. 4(B)) on each of fine movement slider sections 84a and 84b and also making a drive force in the - $\theta_x$  direction (a clockwise direction on the page surface of Fig. 4(B)) on fine movement slider section 84c. Further, main controller 20 can also make the center portion of fine movement stage WFS1 bend in the +Z direction (into a convex shape), for example, by making drive forces in the - $\theta_y$  direction and the + $\theta_y$

direction (a counterclockwise direction and a clockwise direction when viewed from the +Y side, respectively) on fine movement slider sections 84a and 84b, respectively. Main controller 20 can also perform the similar operations with  
5 respect to fine movement stage WFS2.

Incidentally, in the embodiment, as fine movement stage driving systems 64A and 64B, the planar motors of a moving magnet type are used, but this is not intended to be limiting, and planar motors of a moving coil type in which the coil units  
10 are placed at the fine movement slider sections of the fine movement stages and the magnetic units are placed at the guide members of the coarse movement stages can also be used.

Between coupling member 92a of coarse movement stage WCS1 and main section 80 of fine movement stage WFS1, as shown  
15 in Fig. 4(A), a pair of tubes 86a and 86b used to transmit the power usage from the outside to fine movement stage WFS1 are installed. Incidentally, although the illustration is omitted in the drawings including Fig. 4(A), actually, the pair of tubes 86a and 86b are each made up of a plurality of  
20 tubes. One ends of tubes 86a and 86b are connected to the side surface on the +X side of coupling member 92a and the other ends are connected to the inside of main section 80, respectively via a pair of recessed sections 80a (see Fig. 4(C)) with a predetermined depth each of which is formed from  
25 the end surface on the -X side toward the +X direction with a predetermined length, on the upper surface of main section 80. As shown in Fig. 4(C), tubes 86a and 86b are configured not to protrude above the upper surface of fine movement stage WFS1. Between coupling member 92a of coarse movement stage

WCS2 and main section 80 of fine movement stage WFS2 as well, as shown in Fig. 2, a pair of tubes 86a and 86b used to transmit the power usage from the outside to fine movement stage WFS2 are installed.

5           As shown in Fig. 2, one of the tube carriers, tube carrier TCa is connected to the piping member and the wiring member inside coupling member 92a of coarse movement stage WCS1 via tube Ta<sub>2</sub>. As shown in Fig. 3, tube carrier TCa is placed on a stepped section formed at the end on the -X side of base  
10   board 12. Tube carrier TCa is driven in the Y-axis direction following wafer stage WST1, by an actuator such as a liner motor, on the stepped section of base board 12.

          As shown in Fig. 3, the other of the tube carriers, tube carrier TCb is placed on a stepped section formed at the end  
15   on the +X side of base board 12, and is connected to the piping member and the wiring member inside coupling member 92a of coarse movement stage WCS2 via tube Tb<sub>2</sub> (see Fig. 2). Tube carrier TCb is driven in the Y-axis direction following wafer stage WST2, by an actuator such as a liner motor, on the stepped  
20   section of base board 12.

          As shown in Fig. 3, one ends of tubes Ta<sub>1</sub> and Tb<sub>1</sub> are connected to tube carriers TCa and TCb respectively, while the other ends of tubes Ta<sub>1</sub> and Tb<sub>1</sub> are connected to a power usage supplying device externally installed that is not  
25   illustrated (e.g. an electric power supply, a gas tank, a compressor, a vacuum pump or the like). The power usage supplied from the power usage supplying device to tube carrier TCa via tube Ta<sub>1</sub> is supplied to fine movement stage WFS1 via tube Ta<sub>2</sub>, the piping member and the wiring member, which are

not illustrated, housed in coupling member 92a of coarse movement stage WCS1, and tubes 86a and 86b. Similarly, the power usage supplied from the power usage supplying device to tube carrier TCb via tube Tb<sub>1</sub> is supplied to fine movement stage WFS2 via tube Tb<sub>2</sub>, the piping member and the wiring member, which are not illustrated, housed in coupling member 92a of coarse movement stage WCS2, and tubes 86a and 86b.

Next, a measurement system that measures positional information of wafer stages WST1 and WST2 is described.

Exposure apparatus 100 has a fine movement stage position measuring system 70 (see Fig. 6) to measure positional information of fine movement stages WFS1 and WFS2 and coarse movement stage position measuring systems 68A and 68B (see Fig. 6) to measure positional information of coarse movement stages WCS1 and WCS2 respectively.

Fine movement stage position measuring system 70 has a measurement bar 71 shown in Fig. 1. Measurement bar 71 is placed below first sections 14A<sub>1</sub> and 14B<sub>1</sub> that the pair of surface plates 14A and 14B respectively have, as shown in Fig. 3. As is obvious from Figs. 1 and 3, measurement bar 71 is made up of a beam-like member having a rectangular sectional shape with the Y-axis direction serving as its longitudinal direction, and both ends in the longitudinal direction are each fixed to main frame BD in a suspended state via suspended members 74. More specifically, main frame BD and measurement bar 71 are integrated. Incidentally, in the case where a configuration that does not block the movement of the wafer stages is employed for the beam-like member, the support method of the beam-like member is not limited to the both ends support

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but one end in the longitudinal direction can be cantilevered. Further, the beam-like member should be placed below base board 12 described earlier. Furthermore, while the beam-like member is supported by main frame BD, the beam-like member can be arranged on the installation surface (such as a floor surface) via a vibration isolating mechanism. In this case, it is preferable to arrange a measurement device that measures the relative positional relation between main frame BD and the beam-like member. The beam-like member can also be referred to as a member for measurement or the like.

The +Z side half (upper half) of measurement bar 71 is placed between second section 14A<sub>2</sub> of surface plate 14A and second section 14B<sub>2</sub> of surface plate 14B, and the -Z side half (lower half) is housed inside recessed section 12a formed at base board 12. Further, a predetermined clearance is formed between measurement bar 71 and each of surface plates 14A and 14B and base board 12, and measurement bar 71 is in a state mechanically noncontact with the members other than main frame BD. Measurement bar 71 is formed by a material with a relatively low coefficient of thermal expansion (e.g. invar, ceramics, or the like).

At measurement bar 71, as shown in Fig. 5, a first measurement head group 72 used when measuring positional information of the fine movement stage (WFS1 or WFS2) located below projection unit PU and a second measurement head group 73 used when measuring positional information of the fine movement stage (WFS1 or WFS2) located below alignment device 99 are arranged. Incidentally, alignment systems AL1 and AL2<sub>1</sub> to AL2<sub>4</sub> are shown in virtual lines (two-dot chain lines) in

Fig. 5 in order to make the drawing easy to understand. Further, in Fig. 5, the reference signs of alignment systems AL2<sub>1</sub> to AL2<sub>4</sub> are omitted.

As shown in Fig. 5, first measurement head group 72 is placed below projection unit PU and includes a one-dimensional encoder head for X-axis direction measurement (hereinafter, shortly referred to as an X head or an encoder head) 75x, a pair of one-dimensional encoder heads for Y-axis direction measurement (hereinafter, shortly referred to as Y heads or encoder heads) 75ya and 75yb, and three Z heads 76a, 76b and 76c.

X head 75x, Y heads 75ya and 75yb and the three Z heads 76a to 76c are placed in a state where their positions do not vary, inside measurement bar 71. X head 75x is placed on reference axis LV, and Y heads 75ya and 75yb are placed at the same distance apart from X head 75x, on the -X side and the +X side, respectively. In the embodiment, as each of the three encoder heads 75x, 75ya and 75yb, a diffraction interference type head having a configuration in which a light source, a photodetection system (including a photodetector) and various types of optical systems are unitized is used, which is similar to the encoder head disclosed in, for example, PCT International Publication No. 2007/083758 (the corresponding U.S. Patent Application Publication No. 2007/0288121) and the like.

When wafer stage WST1 (or WST2) is located directly under projection optical system PL (see Fig. 1), X head 75x and Y heads 75ya and 75yb each irradiate a measurement beam on grating RG (see Fig. 4(B)) placed on the lower surface of fine

movement stage WFS1 (or WFS2), via a gap between surface plate 14A and surface plate 14B or a light-transmitting section (e.g. an opening) formed at first section 14A<sub>1</sub> of surface plate 14A and first section 14B<sub>1</sub> of surface plate 14B. Further, X head 75x and Y heads 75ya and 75yb each receive diffraction light from grating RG, thereby obtaining positional information within the XY plane (also including rotational information in the  $\theta_z$  direction) of fine movement stage WFS1 (or WFS2). More specifically, an X liner encoder 51 (see Fig. 6) is configured of X head 75x that measures the position of fine movement stage WFS1 (or WFS2) in the X-axis direction using the X diffraction grating that grating RG has. And, a pair of Y liner encoders 52 and 53 (see Fig. 6) are configured of the pair of Y heads 75ya and 75yb that measure the position of fine movement stage WFS1 (or WFS2) in the Y-axis direction using the Y diffraction grating of grating RG. The measurement value of each of X head 75x and Y heads 75ya and 75yb is supplied to main controller 20 (see Fig. 6), and main controller 20 measures (computes) the position of fine movement stage WFS1 (or WFS2) in the X-axis direction using (based on) the measurement value of X head 75x, and the position of fine movement stage WFS1 (or WFS2) in the Y-axis direction based on the average value of the measurement values of the pair of Y head 75ya and 75yb. Further, main controller 20 measures (computes) the position in the  $\theta_z$  direction (rotational amount around the Z-axis) of fine movement stage WFS1 (or WFS2) using the measurement value of each of the pair of Y linear encoders 52 and 53.

In this case, an irradiation point (detection point),

on grating RG, of the measurement beam emitted from X head 75x coincides with the exposure position that is the center of exposure area IA (see Fig. 1) on wafer W. Further, a midpoint of a pair of irradiation points (detection points),  
5 on grating RG, of the measurement beams respectively emitted from the pair of Y heads 75ya and 75yb coincides with the irradiation point (detection point), on grating RG, of the measurement beam emitted from X head 75x. Main controller 20 computes positional information of fine movement stage WFS1  
10 (or WFS2) in the Y-axis direction based on the average of the measurement values of the two Y heads 75ya and 75yb. Therefore, the positional information of fine movement stage WFS1 (or WFS2) in the Y-axis direction is substantially measured at the exposure position that is the center of irradiation area  
15 (exposure area) IA of illumination light IL irradiated on wafer W. More specifically, the measurement center of X head 75x and the substantial measurement center of the two Y heads 75ya and 75yb coincide with the exposure position. Consequently, by using X linear encoder 51 and Y linear encoders 52 and 53,  
20 main controller 20 can perform measurement of the positional information within the XY plane (including the rotational information in the  $\theta_z$  direction) of fine movement stage WFS1 (or WFS2) directly under (on the back side of) the exposure position at all times.

25 As each of Z heads 76a to 76c, for example, a head of a displacement sensor by an optical method similar to an optical pickup used in a CD drive device or the like is used. The three Z heads 76a to 76c are placed at the positions corresponding to the respective vertices of an isosceles



triangle (or an equilateral triangle). Z heads 76a to 76c each irradiate the lower surface of fine movement stage WFS1 (or WFS2) with a measurement beam parallel to the Z-axis from below, and receive reflected light reflected by the surface of the plate on which grating RG is formed (or the formation surface of the reflective diffraction grating). Accordingly, Z heads 76a to 76c configure a surface position measuring system 54 (see Fig. 6) that measures the surface position (position in the Z-axis direction) of fine movement stage WFS1 (or WFS2) at the respective irradiation points. The measurement value of each of the three Z heads 76a to 76c is supplied to main controller 20 (see Fig. 6).

Further, the center of gravity of the isosceles triangle (or the equilateral triangle) whose vertices are at the three irradiation points on grating RG of the measurement beams respectively emitted from the three Z heads 76a to 76c coincides with the exposure position that is the center of exposure area IA (see Fig. 1) on wafer W. Consequently, based on the average value of the measurement values of the three Z heads 76a to 76c, main controller 20 can acquire positional information in the Z-axis direction (surface position information) of fine movement stage WFS1 (or WFS2) directly under the exposure position at all times. Further, main controller 20 measures (computes) the rotational amount in the  $\theta_x$  direction and the  $\theta_y$  direction, in addition to the position in the Z-axis direction, of fine movement stage WFS1 (or WFS2) using (based on) the measurement values of the three Z heads 76a to 76c.

Second measurement head group 73 has an X head 77x that

configures an X liner encoder 55 (see Fig. 6), a pair of Y heads 77ya and 77yb that configure a pair of Y linear encoders 56 and 57 (see Fig. 6), and three Z heads 78a, 78b and 78c that configure a surface position measuring system 58 (see Fig. 6). The respective positional relations of the pair of Y heads 77ya and 77yb and the three Z heads 78a to 78c with X head 77x serving as a reference are similar to the respective positional relations described above of the pair of Y heads 75ya and 75yb and the three Z heads 76a to 76c with X head 75x serving as a reference. An irradiation point (detection point), on grating RG, of the measurement beam emitted from X head 77x coincides with the detection center of primary alignment system AL1. More specifically, the measurement center of X head 77x and the substantial measurement center of the two Y heads 77ya and 77yb coincide with the detection center of primary alignment system AL1. Consequently, main controller 20 can perform measurement of positional information within the XY plane and surface position information of fine movement stage WFS2 (or WFS1) at the detection center of primary alignment system AL1 at all times.

Incidentally, while each of X heads 75x and 77x and Y heads 75ya, 75yb, 77ya and 77yb of the embodiment has the light source, the photodetection system (including the photodetector) and the various types of optical systems (none of which are illustrated) that are unitized and placed inside measurement bar 71, the configuration of the encoder head is not limited thereto. For example, the light source and the photodetection system can be placed outside the measurement bar. In such a case, the optical systems placed inside the

measurement bar, and the light source and the photodetection system are connected to each other via, for example, an optical fiber or the like. Further, a configuration can also be employed in which the encoder head is placed outside the measurement bar and only a measurement beam is guided to the grating via an optical fiber placed inside the measurement bar. Further, the rotational information of the wafer in the  $\theta_z$  direction can be measured using a pair of the X linear encoders (in this case, there should be one Y linear encoder).

Further, the surface position information of the fine movement stage can be measured using, for example, an optical interferometer. Further, instead of the respective heads of first measurement head group 72 and second measurement head group 73, three encoder heads in total, which include at least one XZ encoder head whose measurement directions are the X-axis direction and the Z-axis direction and at least one YZ encoder head whose measurement directions are the Y-axis direction and the Z-axis direction, can be arranged in the placement similar to that of the X head and the pair of Y heads described earlier.

Incidentally, measurement bar 71 can be divided into a plurality of sections. For example, it is also possible that measurement bar 71 is divided into a section having first measurement head group 72 and a section having second measurement head group 73, and the respective sections (measurement bars) detect the relative position with main frame BD, with (the measurement reference surface of) main frame BD serving as a reference and perform control such that the positional relation is constant. In this case, a head unit,

which includes a plurality of encoder heads and Z heads (surface position measuring system), is arranged at both ends of the respective sections (measurement bars), and the positions in the Z-axis direction and the rotational amount in the  $\theta_x$  and  $\theta_y$  directions of the respective sections (measurement bars) can be computed.

When wafer stage WST1 moves between exposure station 200 and measurement station 300 on surface plate 14A, coarse movement stage position measuring system 68A (see Fig. 6) measures positional information of coarse movement stage WCS1 (wafer stage WST1).

As shown in Fig. 2, coarse movement stage position measuring system 68A includes an interferometer system that has two Y interferometers 18YA<sub>1</sub> and 18YA<sub>2</sub> and three X interferometers 18XA<sub>1</sub>, 18XA<sub>2</sub> and 18XA<sub>3</sub>. Y interferometer 18YA<sub>2</sub> is placed on the +Y side of surface plate 14A. Y interferometer 18YA<sub>2</sub> irradiates reflection surface 17Y<sub>2</sub> with a measurement beam and receives a reflected beam from reflection surface 17Y<sub>2</sub>, thereby measuring the Y-position of reflection surface 17Y<sub>2</sub>, or more specifically, the Y-position of wafer stage WST1. Y interferometer 18YA<sub>1</sub> is placed on the -Y side of surface plate 14A. Similarly to Y interferometer 18YA<sub>2</sub>, for example, as shown in Figs. 12 and 13, Y interferometer 18YA<sub>1</sub> irradiates reflection surface 17Y<sub>1</sub> with a measurement beam and receives a reflected beam from reflection surface 17Y<sub>1</sub>, thereby measuring the Y-position of wafer stage WST1. Y interferometers 18YA<sub>1</sub> and 18YA<sub>2</sub> are mainly used when wafer stage WST1 is located in the -Y side half and the +Y side half, respectively, on surface plate 14A.

Meanwhile, X interferometers 18XA<sub>1</sub>, 18XA<sub>2</sub> and 18XA<sub>3</sub> are placed on the -X side of surface plate 14A, at a predetermined distance in the Y-axis direction. X interferometer 18XA<sub>3</sub> irradiates reflection surface 17X with two measurement beams along an axis (measurement axis) parallel to the X-axis that is orthogonal to optical axis AX of projection optical system PL and reference axis LV, and receives reflected beams from reflection surface 17X, thereby measuring the X-position and  $\theta_z$  rotation (yawing amount) of wafer stage WST1. Likewise, X interferometers 18XA<sub>1</sub> and 18XA<sub>2</sub> also each irradiate reflection surface 17X with two measurement beams and receive reflected beams from reflection surface 17X, thereby measuring the X-position and  $\theta_z$  rotation (yawing amount) of wafer stage WST1. In this case, the distance between X interferometers 18XA<sub>1</sub>, 18XA<sub>2</sub> and 18XA<sub>3</sub> adjacent to each other in the Y-axis direction is set such that any of the X interferometers is surely opposed to reflection surface 17X of wafer stage WST1. Main controller 20 (see Fig. 6) constantly measures the X-position and  $\theta_z$  rotation (yawing amount) of wafer stage WST1 that moves on surface plate 14A, using X interferometers 18XA<sub>1</sub>, 18XA<sub>2</sub> and 18XA<sub>3</sub> by switching them according to the Y-position of wafer stage WST1.

Incidentally, the configuration of coarse movement stage position measuring system 68A (and coarse movement stage position measuring system 68B to be described later on) is not limited to the configuration described above, and an encoder system or a combination of an optical interferometer system and an encoder system can also be employed. In the case where coarse movement stage position measuring system 68A

includes the encoder system, for example, a configuration can be employed in which the positional information of coarse movement stage WCS1 is measured by irradiating a scale (e.g. two-dimensional grating) fixed (or formed) on the upper  
5 surface of coarse movement stage WCS1 with measurement beams from a plurality of encoder heads fixed to main frame BD in a suspended state along the movement course of wafer stage WST1 and receiving the diffraction light of the measurement beams.

10 When wafer stage WST2 moves between exposure station 200 and measurement station 300 on surface plate 14B, coarse movement stage position measuring system 68B (see Fig. 6) measures positional information of coarse movement stage WCS2 (wafer stage WST2), similarly to coarse movement stage  
15 position measuring system 68A.

As shown in Fig. 2, coarse movement stage position measuring system 68B includes an interferometer system that has two Y interferometers 18YB<sub>1</sub> and 18YB<sub>2</sub> and three X interferometers 18XB<sub>1</sub>, 18XB<sub>2</sub> and 18XB<sub>3</sub>. Y interferometer 18YB<sub>1</sub>  
20 is placed on the -Y side of surface plate 14B. Y interferometer 18YB<sub>1</sub> irradiates reflection surface 17Y<sub>1</sub> with a measurement beam and receives a reflected beam from reflection surface 17Y<sub>1</sub>, thereby measuring the Y-position of reflection surface 17Y<sub>1</sub>, or more specifically, the Y-position of wafer stage WST2.  
25 Y interferometer 18YB<sub>2</sub> is placed on the +Y side of surface plate 14B. Similarly to Y interferometer 18YB<sub>1</sub>, for example, when wafer stage WST2 is located at the position as shown in Figs. 12 and 13, Y interferometer 18YB<sub>2</sub> irradiates reflection surface 17Y<sub>2</sub> with a measurement beam and receives a reflected

beam from reflection surface 17Y<sub>2</sub>, thereby measuring the Y-position of wafer stage WST2. Y interferometers 18YB<sub>1</sub> and 18YB<sub>2</sub> are mainly used when wafer stage WST2 is located in the -Y side half and the +Y side half, respectively, on surface plate 14B.

Meanwhile, X interferometers 18XB<sub>1</sub>, 18XB<sub>2</sub> and 18XB<sub>3</sub> are placed on the +X side of surface plate 14B, at a predetermined distance in the Y-axis direction. X interferometer 18XB<sub>3</sub> irradiates reflection surface 17X with two measurement beams along an axis (measurement axis) parallel to the X-axis that is orthogonal to optical axis AX of projection optical system PL and reference axis LV, and receives reflected beams from reflection surface 17X, thereby measuring the X-position and  $\theta_z$  rotation (yawing amount) of wafer stage WST2. Likewise, X interferometers 18XB<sub>1</sub> and 18XB<sub>2</sub> also each irradiate reflection surface 17X with two measurement beams and receive reflected beams from reflection surface 17X, thereby measuring the X-position and  $\theta_z$  rotation (yawing amount) of wafer stage WST2. In this case, the distance between X interferometers 18XB<sub>1</sub>, 18XB<sub>2</sub> and 18XB<sub>3</sub> adjacent to each other in the Y-axis direction is set such that any of the X interferometers is surely opposed to reflection surface 17X of wafer stage WST2. Main controller 20 (see Fig. 6) constantly measures the X-position and  $\theta_z$  rotation (yawing amount) of wafer stage WST2 that moves on surface plate 14B, using X interferometers 18XB<sub>1</sub>, 18XB<sub>2</sub> and 18XB<sub>3</sub> by switching them according to the Y-position of wafer stage WST2.

As is obvious from Fig. 2, each of Y interferometers 18YA<sub>1</sub> and 18YA<sub>2</sub> and X interferometers 18XA<sub>1</sub>, 18XA<sub>2</sub> and 18XA<sub>3</sub> that

configure coarse movement stage position measuring system 68A is placed symmetric with each of Y interferometers 18YB<sub>1</sub> and 18YB<sub>2</sub> and X interferometers 18XB<sub>1</sub>, 18XB<sub>2</sub> and 18XB<sub>3</sub> that configure a part of coarse movement stage position measuring system 68B, with respect to reference axis LV.

Main controller 20 respectively controls the positions of coarse movement stages WCS1 and WCS2 (wafer stages WST1 and WST2) by individually controlling coarse movement stage driving systems 62A and 62B, based on the measurement values of coarse movement stage position measuring systems 68A and 68B.

Further, exposure apparatus 100 is also equipped with a relative position measuring system 66A and a relative position measuring system 66B (see Fig. 6) that measure the relative position between coarse movement stage WCS1 and fine movement stage WFS1 and the relative position between coarse movement stage WCS2 and fine movement stage WFS2, respectively. While the configuration of relative position measuring systems 66A and 66B is not limited in particular, relative position measuring systems 66A and 66B can each be configured of, for example, a gap sensor including a capacitance sensor. In this case, the gap sensor can be configured of, for example, a probe section fixed to coarse movement stage WCS1 (or WCS2) and a target section fixed to fine movement stage WFS1 (or WFS2). Incidentally, the configuration of the relative position measuring system is not limited thereto, but for example, the relative position measuring system can be configured using, for example, a liner encoder system, an optical interferometer system or the like.



Fig. 6 shows a block diagram that shows input/output relations of main controller 20 that is configured of a control system of exposure apparatus 100 as the central component and performs overall control of the respective components. Main controller 20 includes a workstation(or a microcomputer) and the like, and performs overall control of the respective components of exposure apparatus 100 such as local liquid immersion device 8, surface plate driving systems 60A and 60B, coarse movement stage driving systems 62A and 62B, and fine movement stage driving systems 64A and 64B.

Next, a parallel exposure operation using the two wafer stages WST1 and WST2 is described with reference to Figs. 7 to 13. Note that during the exposure operation, main controller 20 controls liquid supply device 5 and liquid recovery device 6 as described earlier and a constant quantity of liquid Lq is held directly under tip lens 191 of projection optical system PL, and thereby a liquid immersion area is formed at all times.

Fig. 7 shows a state where exposure by a step-and-scan method is performed on wafer W mounted on fine movement stage WFS1 of wafer stage WST1 in exposure station 200, and in parallel with this exposure, wafer exchange is performed between a wafer carrier mechanism (not illustrated) and fine movement stage WFS2 of wafer stage WST2 at the second loading position.

Main controller 20 performs the exposure operation by a step-and-scan method by repeating an inter-shot movement (stepping between shots) operation of moving wafer stage WST1 to a scanning starting position (acceleration starting

position) for exposure of each shot area on wafer W, based on the results of wafer alignment (e.g. information obtained by converting an arrangement coordinate of each shot area on wafer W obtained by an Enhanced Global Alignment (EGA) into  
5 a coordinate with the second fiducial mark on measurement plate FM1 serving as a reference) and reticle alignment and the like that have been performed beforehand, and a scanning exposure operation of transferring a pattern formed on reticle R onto each shot area on wafer W by a scanning exposure method. During  
10 this step-and-scan operation, surface plates 14A and 14B exert the function as the counterbalances, as described previously, according to movement of wafer stage WST1, for example, in the Y-axis direction during scanning exposure. Further, main controller 20 gives the initial velocity to coarse movement  
15 stage WCS1 when driving fine movement stage WFS1 in the X-axis direction for the stepping operation between shots, and thereby coarse movement stage WCS1 functions as a local counterbalance with respect to fine movement stage WFS1. Consequently, the movement of wafer stage WST1 (coarse  
20 movement stage WCS1 and fine movement stage WFS1) does not cause vibration of surface plates 14A and 14B and does not adversely affect wafer stage WST2.

The exposure operations described above are performed in a state where liquid Lq is held in the space between tip  
25 lens 191 and wafer W (wafer W and plate 82 depending on the position of a shot area), or more specifically, by liquid immersion exposure.

In exposure apparatus 100 of the embodiment, during a series of the exposure operations described above, main

controller 20 measures the position of fine movement stage WFS1 using first measurement head group 72 of fine movement stage position measuring system 70 and controls the position of fine movement stage WFS1 (wafer W) based on this measurement  
5 result.

The wafer exchange is performed by unloading a wafer that has been exposed from fine movement stage WFS2 and loading a new wafer onto fine movement stage WFS2 by the wafer carrier mechanism that is not illustrated, when fine movement stage  
10 WFS2 is located at the second loading position. In this case, the second loading position is a position where the wafer exchange is performed on wafer stage WST2, and in the embodiment, the second loading position is to be set at the position where fine movement stage WFS2 (wafer stage WST2)  
15 is located such that measurement plate FM2 is positioned directly under primary alignment system AL1.

During the wafer exchange described above, and after the wafer exchange, while wafer stage WST2 stops at the second loading position, main controller 20 executes reset  
20 (resetting of the origin) of second measurement head group 73 of fine movement stage position measuring system 70, or more specifically, encoders 55, 56 and 57 (and surface position measuring system 58), prior to start of wafer alignment (and the other pre-processing measurements) with respect to the  
25 new wafer W.

When the wafer exchange (loading of the new wafer W) and the reset of encoders 55, 56 and 57 (and surface position measuring system 58) have been completed, main controller 20 detects the second fiducial mark on measurement plate FM2 using

primary alignment system AL1. Then, main controller 20 detects the position of the second fiducial mark with the index center of primary alignment system AL1 serving as a reference, and based on the detection result and the result of position measurement of fine movement stage WFS2 by encoders 55, 56 and 57 at the time of the detection, computes the position coordinate of the second fiducial mark in an orthogonal coordinate system (alignment coordinate system) with reference axis La and reference axis LV serving as coordinate axes.

Next, as shown in Fig. 8, main controller 20 performs the EGA while measuring the position coordinate of fine movement stage WFS2 (wafer stage WST2) in the alignment coordinate system using encoders 55, 56 and 57 (see Fig. 6). To be more specific, as disclosed in, for example, U.S. Patent Application Publication No. 2008/0088843 and the like, main controller 20 moves wafer stage WST2, or more specifically, coarse movement stage WCS2 that supports fine movement stage WFS2 in, for example, the Y-axis direction. Then, main controller 20 sets the position of fine movement stage WFS2 at a plurality of positions in the movement course, and at each position setting, detects the position coordinates, in the alignment coordinate system, of alignment marks at alignment shot areas (sample shot areas) using at least one of alignment systems AL1 and AL2<sub>2</sub> and AL2<sub>4</sub>.

In this case, in conjunction with the movement operation of wafer stage WST2 in the Y-axis direction described above, alignment systems AL1 and AL2<sub>2</sub> to AL2<sub>4</sub> respectively detect a plurality of alignment marks (sample marks) disposed along

the X-axis direction that are sequentially placed within the detection areas (e.g. corresponding to the irradiation areas of detection light). Therefore, on the measurement of the alignment marks described above, wafer stage WST2 is not driven  
5 in the X-axis direction.

Then, based on the position coordinates of the plurality of alignment marks arranged at the sample shot areas on wafer W and the design position coordinates, main controller 20 executes statistical computation (EGA computation) disclosed  
10 in, for example, U.S. Patent No. 4,780, 617 and the like, and computes the position coordinates (arrangement coordinates) of the plurality of shot areas in the alignment coordinate system.

Further, in exposure apparatus 100 of the embodiment,  
15 since measurement station 300 and exposure station 200 are spaced apart, main controller 20 subtracts the position coordinate of the second fiducial mark that has previously been detected from the position coordinate of each of the shot areas on wafer W that has been obtained as a result of the  
20 wafer alignment, thereby obtaining the position coordinates of the plurality of shot areas on wafer W with the position of the second fiducial mark serving as the origin.

Normally, the above-described wafer exchange and wafer alignment sequence is completed earlier than the exposure  
25 sequence. Therefore, when the wafer alignment has been completed, main controller 20 drives wafer stage WST2 in the +X direction to move wafer stage WST2 to a predetermined standby position on surface plate 14B, as shown in Fig. 9. In this case, when wafer stage WST2 is driven in the +X

direction, fine movement stage WFS goes out of a measurable range of fine movement stage position measuring system 70 (i.e. the measurement beams emitted from second measurement head group 73 move off from grating RG). Therefore, based on the measurement values of fine movement stage position measuring system 70 (encoders 55, 56 and 57) and the measurement values of relative position measuring system 66B, main controller 20 measures the position of coarse movement stage WCS2 using coarse movement stage position measuring system 68B, and based on the measurement result, controls the position of wafer stage WST2. More specifically, position measurement of wafer stage WST2 within the XY plane is switched from the measurement using encoders 55, 56 and 57 of fine movement stage position measuring system 70 to the measurement using Y interferometer 18YB<sub>1</sub> and X interferometer 18XB<sub>1</sub> of coarse movement stage position measuring system 68B. Then, main controller 20 makes wafer stage WST2 wait at the predetermined standby position described above until exposure on wafer W on fine movement stage WFS1 is completed.

When the exposure on wafer W on fine movement stage WFS1 has been completed, main controller 20 starts to drive wafer stages WST1 and WST2 severally toward a right-side scrum position shown in Fig. 10. When wafer stage WST1 is driven in the -X direction toward the right-side scrum position, fine movement stage WFS1 goes out of the measurable range of fine movement stage position measuring system 70 (encoders 51, 52 and 53 and surface position measuring system 54) (i.e. the measurement beams emitted from first measurement head group 72 move off from grating RG). Therefore, main controller 20

measures the position of coarse movement stage WCS1 using coarse movement stage position measuring system 68A, and based on the measurement result, controls the position of wafer stage WST1. More specifically, main controller 20 switches  
5 position measurement of wafer stage WST1 within the XY plane from the measurement using encoders 51, 52 and 53 of fine movement stage position measuring system 70 to the measurement using Y interferometer 18YA<sub>2</sub> and X interferometer 18XA<sub>3</sub> of coarse movement stage position measuring system 68A.

10 Further, main controller 20 measures the position of wafer stage WST2 using coarse movement stage position measuring system 68B, and based on the measurement result, as shown in Fig. 9, drives wafer stage WST2 in the +Y direction on surface plate 14B (see an outlined arrow in Fig. 9). On  
15 this operation, as shown in Figs. 9 and 10, the X interferometer used in the position measurement of wafer stage WST2 is sequentially switched to X interferometers 18XB<sub>1</sub>, 18XB<sub>2</sub> and 18XB<sub>3</sub> according to the Y-position of wafer stage WST2, and also the Y interferometer used in the position measurement of wafer  
20 stage WST2 is switched from Y interferometer 18YB<sub>1</sub> to Y interferometer 18YB<sub>2</sub>. Note that surface plate 14B functions as the counter mass owing to the action of a reaction force of a drive force of wafer stage WST2.

Further, in parallel with the movement of wafer stages  
25 WST1 and WST2 toward the right-side scrum position described above, main controller 20 drives fine movement stage WFS1 in the +X direction based on the measurement values of relative position measuring system 66A and causes fine movement stage WFS1 to be in proximity to or in contact with coarse movement

stage WCS1, and also drives fine movement stage WFS2 in the  
-X direction based on the measurement values of relative  
position measuring system 66B and causes fine movement stage  
WFS2 to be in proximity to or in contact with coarse movement  
5 stage WCS2.

Then, in a state where both wafer stages WST1 and WST2  
have moved to the right-side scrum position, wafer stage WST1  
and wafer stage WST2 go into a scrum state of being in proximity  
or in contact in the X-axis direction, as shown in Fig. 10.  
10 Simultaneously with this state, fine movement stage WFS1 and  
coarse movement stage WCS1 go into a scrum state, and coarse  
movement stage WCS2 and fine movement stage WFS2 go into a  
scrum state. Then, the upper surfaces of fine movement stage  
WFS1, coupling member 92b of coarse movement stage WCS1,  
15 coupling member 92b of coarse movement stage WCS2 and fine  
movement stage WFS2 form a fully flat surface that is  
apparently integrated.

As shown in Fig. 10, while keeping the scrum states  
described above, main controller 20 drives wafer stage WST1  
20 in a direction indicated by a black arrow (-X direction) based  
on the measurement result of coarse movement stage position  
measuring system 68A, and at the same time, drives wafer stage  
WST2 in a direction indicated by an outlined arrow (-X  
direction) based on the measurement result of coarse movement  
25 stage position measuring system 68B. As wafer stages WST1 and  
WST2 move in the -X direction while keeping the three scrum  
states described above, the liquid immersion area (liquid Lq)  
formed between tip lens 191 and fine movement stage WFS1  
sequentially moves onto fine movement stage WFS1, coupling



member 92b of coarse movement stage WCS1, coupling member 92b of coarse movement stage WCS2, and fine movement stage WFS2. Fig. 10 shows a state just before starting the movement of the liquid immersion area (liquid Lq). Note that in the case where wafer stage WST1 and wafer stage WST2 are driven while the above-described three scrum states are kept, it is preferable that a gap (clearance) between wafer stage WST1 and wafer stage WST2, a gap (clearance) between fine movement stage WFS1 and coarse movement stage WCS1 and a gap (clearance) between coarse movement stage WCS2 and fine movement stage WFS2 are set such that leakage of liquid Lq is prevented or restrained. In this case, the proximity includes the case where the gap (clearance) between the two members in the scrum state is zero, or more specifically, the case where both the members are in contact.

After the liquid immersion area (liquid Lq) has been moved onto fine movement stage WFS2, main controller 20 drives fine movement stage WFS1 in the -X direction based on the measurement value of relative position measuring system 66A and releases the scrum state of fine movement stage WFS1 and coarse movement stage WCS1, and also drives fine movement stage WFS2 in the +X direction based on the measurement value of relative position measuring system 66B and release the scrum state of fine movement stage WFS2 and coarse movement stage WCS2. Furthermore, main controller 20 releases the scrum state of wafer stages WST1 and WST2.

When the movement of the liquid immersion area (liquid Lq) onto fine movement stage WFS2 has been completed, wafer stage WST1 has moved onto surface plate 14A. Then, main

controller 20 moves wafer stage WST1 in the -Y direction on surface plate 14A as shown by a black arrow in Fig. 11 and further moves wafer stage WST1 in the +X direction as shown in Fig. 12, while measuring the position of wafer stage WST1 using coarse movement stage position measuring system 68A, so as to move wafer stage WST1 to the first loading position. On this operation, as shown in Figs. 11 and 12, the X interferometer used in the position measurement of wafer stage WST1 is sequentially switched to X interferometers 18XA<sub>3</sub>, 18XA<sub>2</sub> and 18XA<sub>1</sub> according to the Y-position of wafer stage WST1, and also the Y interferometer used in the position measurement of wafer stage WST1 is switched from Y interferometer 18YA<sub>2</sub> to Y interferometer 18YA<sub>1</sub>. Note that, when wafer stage WST1 moves in the -Y direction, surface plate 14A functions as the counter mass owing to the action of a reaction force of the drive force. Further, when wafer stage WST1 moves in the +X direction, surface plate 14A can be made to function as the counter mass owing to the action of a reaction force of the drive force.

As shown in Fig. 13, after wafer stage WST1 has reached the first loading position, main controller 20 switches position measurement of wafer stage WST1 within the XY plane from the measurement using coarse movement stage position measuring system 68A to the measurement using fine movement stage position measuring system 70 (encoders 55, 56 and 57 included in second measurement head group 73).

In parallel with the movement of wafer stage WST1 described above, main controller 20 drives wafer stage WST2 and sets the position of measurement plate FM2 at directly

under projection optical system PL, as shown in Fig. 12. Prior to this operation, main controller 20 has switched position measurement of wafer stage WST2 within the XY plane from the measurement using coarse movement stage position measuring system 68B to the measurement using fine movement stage position measuring system 70 (encoders 51, 52 and 53). Then, the pair of first fiducial marks on measurement plate FM2 are detected using reticle alignment systems RA<sub>1</sub> and RA<sub>2</sub> and the relative position of projected images, on the wafer, of the reticle alignment marks on reticle R that correspond to the first fiducial marks are detected. Note that this detection is performed via projection optical system PL and liquid Lq that forms the liquid immersion area.

Based on the relative positional information detected as above and the positional information of each of the shot areas on wafer W with the second fiducial mark on fine movement stage WFS2 serving as a reference that has been previously obtained, main controller 20 computes the relative positional relation between the projection position of the pattern of reticle R (the projection center of projection optical system PL) and each of the shot areas on wafer W mounted on fine movement stage WFS2. While controlling the position of fine movement stage WFS2 (wafer stage WST2) based on the computation results, main controller 20 transfers the pattern of reticle R onto each shot area on wafer W mounted on fine movement stage WFS2 by a step-and-scan method, which is similar to the case of wafer W mounted on fine movement stage WFS1 described earlier. Fig. 13 shows a state where the pattern of reticle R is transferred onto each shot area on wafer W in this manner.

In parallel with the above-described exposure operation on wafer W on fine movement stage WFS2, main controller 20 performs the wafer exchange between the wafer carrier mechanism (not illustrated) and wafer stage WST1 at the first loading position and mounts a new wafer W on fine movement stage WFS1. In this case, the first loading position is a position where the wafer exchange is performed on wafer stage WST1, and in the embodiment, the first loading position is to be set at the position where fine movement stage WFS1 (wafer stage WST1) is located such that measurement plate FM1 is positioned directly under primary alignment system AL1.

Then, main controller 20 detects the second fiducial mark on measurement plate FM1 using primary alignment system AL1. Note that, prior to the detection of the second fiducial mark, main controller 20 executes reset (resetting of the origin) of second measurement head group 73 of fine movement stage position measuring system 70, or more specifically, encoders 55, 56 and 57 (and surface position measuring system 58), in a state where wafer stage WST1 is located at the first loading position. After that, main controller 20 performs wafer alignment (EGA) using alignment systems AL1 and AL2<sub>1</sub> to AL2<sub>4</sub>, which is similar to the above-described one, with respect to wafer W on fine movement stage WFS1, while controlling the position of wafer stage WST1.

When the wafer alignment (EGA) with respect to wafer W on fine movement stage WFS1 has been completed and also the exposure on wafer W on fine movement stage WFS2 has been completed, main controller 20 drives wafer stages WST1 and WST2 toward a left-side scrum position. This left-side scrum

position indicates a positional relation in which wafer stages WST1 and WST2 are located at positions that are bilaterally symmetric with the positions of the wafer stages in the right-side scrum position shown in Fig. 10, with respect to reference axis LV described above. Measurement of the position of wafer stage WST1 during the drive toward the left-side scrum position is performed in a similar procedure to that of the position measurement of wafer stage WST2 described earlier.

At this left-side scrum position as well, wafer stage WST1 and wafer stage WST2 go into the scrum state described earlier, and concurrently with this state, fine movement stage WFS1 and coarse movement stage WCS1 go into the scrum state and coarse movement stage WCS2 and fine movement stage WFS2 go into the scrum state. Then, the upper surfaces of fine movement stage WFS1, coupling member 92b of coarse movement stage WCS1, coupling member 92b of coarse movement stage WCS2 and fine movement stage WFS2 form a fully flat surface that is apparently integrated.

Main controller 20 drives wafer stages WST1 and WST2 in the +X direction that is reverse to the previous direction, while keeping the three scrum states described above. According this drive, the liquid immersion area (liquid Lq) formed between tip lens 191 and fine movement stage WFS2 sequentially moves onto fine movement stage WFS2, coupling member 92b of coarse movement stage WCS2, coupling member 92b of coarse movement stage WCS1 and fine movement stage WFS1, which is reverse to the previously described order. As a matter of course, also when the wafer stages are moved while

the scrub states are kept, the position measurement of wafer stages WST1 and WST2 is performed, similarly to the previously described case. When the movement of the liquid immersion area (liquid Lq) has been completed, main controller 20 starts exposure on wafer W on wafer stage WST1 in the procedure similar to the previously described procedure. In parallel with this exposure operation, main controller 20 drives wafer stage WST2 toward the second loading position in a manner similar to the previously described manner, exchanges wafer W that has been exposed on wafer stage WST2 with a new wafer W, and executes the wafer alignment with respect to the new wafer W.

After that, main controller 20 repeatedly executes the parallel processing operations using wafer stages WST1 and WST2 described above.

As described above, in exposure apparatus 100 of the embodiment, during the exposure operation and during the wafer alignment (mainly, during the measurement of the alignment marks), first measurement head group 72 and second measurement head group 73 fixed to measurement bar 71 are respectively used in the measurement of the positional information (the positional information within the XY plane and the surface position information) of fine movement stage WFS1 (or WFS2) that holds wafer W. And, since encoder heads 75x, 75ya and 75yb and Z heads 76a to 76c that configure first measurement head group 72, and encoder heads 77x, 77ya and 77yb and Z heads 78a to 78c that configure second measurement head group 73 can respectively irradiate grating RG placed on the bottom surface of fine movement stage WFS1 (or WFS2) with measurement beams from directly below at the shortest distance,

measurement error caused by temperature fluctuation of the surrounding atmosphere of wafer stage WST1 or WST2, e.g., air fluctuation is reduced, and high-precision measurement of the positional information of fine movement stage WFS can be performed.

Moreover, in exposure apparatus 100 of the embodiment, when the liquid immersion area (liquid Lq) formed on one of wafer stages WST1 and WST2 is moved onto the other of wafer stages WST1 and WST2, positional information of one of the wafer stages is measured by first measurement head group 72 of fine movement stage position measuring system 70 and positional information of the other of the wafer stages or both the wafer stages is measured by coarse movement stage position measuring systems 68A and 68B. Wafer stages WST1 and WST2 are driven while the scrum state of being in proximity to each other is maintained based on the measurement result, and thereby the liquid immersion area (liquid Lq) formed on one of the wafer stages can be moved to the other of the wafer stages.

Further, exposure apparatus 100 of the embodiment is equipped with fine movement stage position measuring system 70 (first and second measurement head groups 72 and 73) that measures positional information of fine movement stages WFS1 and WFS2 that move between exposure station 200 (below projection unit PU) and measurement station 300 (below alignment device 99), and coarse movement stage position measuring systems 68A and 68B that measure positional information of coarse movement stages WCS1 and WCS2 that move between exposure station 200 and measurement station 300.

Accordingly, based on the measurement results of fine movement stage position measuring system 70 and coarse movement stage position measuring systems 68A and 68B, wafer stages WST1 and WST2 can be moved between exposure station 200 and measurement station 300.

Further, according to exposure apparatus 100 of the embodiment, based on the measurement results of fine movement stage position measuring system 70 (first measurement head group 72) and coarse movement stage position measuring systems 68A and 68B, main controller 20 causes coarse movement stages WCS1 and WCS2 and fine movement stages WFS1 and WFS2, which wafer stages WST1 and WST2 respectively have, to be in proximity (or be in contact) in the X-axis direction, and also causes wafer stages WST1 and WST2 to be in proximity (or be in contact) in the X-axis direction, and moves wafer stages WST1 and WST2 integrally in the X-axis direction while maintaining the proximity states. Accordingly, the liquid immersion area (liquid Lq) formed on one of wafer stages WST1 and WST2 can be moved onto the other of wafer stages WST1 and WST2.

Incidentally, in the embodiment above, the liquid immersion area (liquid Lq) is moved between fine movement stage WFS1 and fine movement stage WFS2 via coupling members 92b which coarse movement stages WCS1 and WCS2 are respectively equipped with. In the case where coupling members 92b are not necessary in terms of the configuration of coarse movement stages WCS1 and WCS2, or more specifically, in the case where coarse movement stages WCS1 and WCS2 are configured into a U-like shape by coupling the pair of coarse movement slider



sections 90a and 90b using only coupling member 92a as in a modified example shown in Fig. 14, the liquid immersion area (liquid Lq) can be directly moved between fine movement stage WFS1 and fine movement stage WFS2. Fig. 14 shows the state  
5 where both wafer stages WST1 and WST2 corresponding to the state shown in Fig. 10 have moved to the right-side scrum position.

In this modified example of Fig. 14, in parallel with movement of wafer stages WST1 and WST2 toward the right-side  
10 scrum position, main controller 20 drives fine movement stage WFS1 in the +X direction with respect to coarse movement stage WCS1 based on the measurement value of relative position measuring system 66A and also drives fine movement stage WFS2  
15 in the -X direction with respect to coarse movement stage WCS2 based on the measurement value of relative position measuring system 66B. Then, when both wafer stages WST1 and WST2 have moved to the right-side scrum position, as shown in Fig. 14, fine movement stage WFS1 and fine movement stage WFS2 go into  
20 a scrum state of being in proximity or in contact in the X-axis direction. At this point in time, the upper surfaces of fine movement stage WFS1 and fine movement stage WFS2 form a fully flat surface that is apparently integrated. Main controller  
25 20 drives wafer stage WST1 in the -X direction as indicated by a black arrow based on the measurement result of coarse movement stage position measuring system 68A while keeping the scrum state, and at the same time, drives wafer stage WST2 in the -X direction as indicated by an outlined arrow based on the measurement result of coarse movement stage position measuring system 68B. According to movement of both wafer

stages WST1 and WST2, the liquid immersion area (liquid Lq) formed between tip lens 191 and fine movement stage WFS1 moves onto fine movement stage WFS2.

## 5 - Second Embodiment

A second embodiment of the present invention is described below with reference to Figs. 15 to 23. Herein, for the components that are the same as or equivalent to those in the first embodiment described above, the same or similar reference signs are used and the description thereof is omitted or simplified.

Fig. 15 shows a plan view of an exposure apparatus 1000 of the present second embodiment. As is obvious when comparing Fig. 15 and Fig. 2, although exposure apparatus 1000 of the present second embodiment is much different in the configuration of a wafer stage that holds wafer W from exposure apparatus 100 of the first embodiment described earlier, the configuration of the other sections is substantially similar. Therefore, in the description below, the different point is focused on and described from the viewpoint of preventing the redundant description.

Fig. 16(A) shows a plan view of a wafer stage WST3 which exposure apparatus 1000 is equipped with, and Fig. 16(B) shows a cross sectional view taken along the line B-B of Fig. 16(A). Wafer stage WST3 is a tabular member as a whole that is made up of a member 180 corresponding to the fine movement stage in the first embodiment described earlier (a tabular member that holds wafer W on its upper surface and has grating RG on its lower surface) that is integrally fixed to a member

190 with a rectangular frame shape in a planar view corresponding to the coarse movement stage. At ends on the +Y side and the -Y side of wafer stage WST3, magnetic units 196a and 196b are arranged that configure, together with coil units (the illustration is omitted) respectively inside first sections 14A<sub>1</sub> and 14B<sub>1</sub> of surface plates 14A and 14B, a planar motor of a magnetic levitation type that is capable of generating a thrust in the directions of six degrees of freedom. Wafer stage WST3 is driven by this planar motor so as to follow the XY plane on the surface plates. More specifically, the planar motor functions as stage driving systems 61A and 61B (see Fig. 18) in both coarse and fine movements. Incidentally, in this case as well, the planar motor can be of a moving magnet type or a moving coil type, and either type can be applied.

15       The -X side section of member 190 that configures the end on the -X side of wafer stage WST3 is formed so as to be hollow, similar to coupling member 92a in the first embodiment described earlier, and inside member 190, a piping member, a wiring member and the like, which are not illustrated, used to supply the power usage to wafer stage WST3 are housed. Further, inside wafer stage WST3, various types of optical members (e.g. an aerial image measuring instrument, an uneven illuminance measuring instrument, an illuminance monitor, a wavefront aberration measuring instrument and the like) can be housed.

Further, the mirror polishing is applied to each of the side surface on the +Y side, the side surface on the -Y side and the side surface on the -X side of wafer stage WST3, and reflection surfaces 17Y<sub>2</sub>, 17Y<sub>1</sub> and 17X are formed. These

reflection surfaces are used in position measurement of wafer stage WST3 by interferometer systems 67A and 67B that are described later. Instead of reflection surfaces 17Y<sub>2</sub>, 17Y<sub>1</sub> and 17X, a movable mirror made up of a planar mirror can be  
5 arranged at wafer stage WST3.

As is obvious from Fig. 15, a wafer stage WST4 is configured similar to wafer stage WST3 including the drive systems and the position measurement systems, except that wafer stage WST4 is placed in a state mirror-reversed with  
10 respect to wafer stage WST3.

Next, a measurement system that measures positional information of wafer stages WST3 and WST4 is described. Exposure apparatus 1000 is equipped with a stage position measuring system 70 (see Fig. 18) that measures positional  
15 information of wafer stages WST3 and WST4 in exposure station 200 (below projection unit PU) and in measurement station 300 (below alignment device 99) and an auxiliary stage position measuring system 79 and interferometer systems 67A and 67B (see Fig. 18) that measure positional information of wafer  
20 stages WST3 and WST4 in areas on surface plates 14A and 14B other than exposure station 200 and measurement station 300.

Stage position measuring system 70 is configured substantially similar to fine movement stage position measuring system 70 in the first embodiment. More  
25 specifically, as shown in Fig. 17, at measurement bar 71 that is placed below surface plates 14A and 14B (first sections 14A<sub>1</sub> and 14B<sub>1</sub>), first measurement head group 72 and second measurement head group 73 are arranged. First and second measurement head groups 72 and 73 are placed below projection

unit PU and alignment device 99 respectively, and are used to measure positional information of wafer stages WST3 and WST4 located in exposure station 200 and measurement station 300.

5        Auxiliary stage position measuring system 79 is used to measure positional information of wafer stages WST3 and WST4 located in an area (hereinafter, referred to as a scrum area for the sake of convenience) between exposure station 200 and measurement station 300. Auxiliary stage position measuring  
10       system 79 includes a third measurement head group 79H arranged at measurement bar 71.

As shown in Fig. 17, third measurement head group 79H is placed between first measurement head group 72 and second measurement head group 73, and includes an X head 79x and a  
15       pair of Y heads 79ya and 79yb. X head 79x is placed on reference axis LV and Y heads 79ya and 79yb are placed at the same distance apart from X head 79x, on the -X side and the +X side, respectively. As each of theses X head 79x and Y heads 79ya and 79yb, a diffraction interference type head that is similar  
20       to the above-described one is used.

When wafer stage WST3 or WST4 is located in the scrum area, X head 79x and Y heads 79ya and 79yb each measure the X-position information or the Y-position information of wafer stage WST3 or WST4, by irradiating a measurement beam on  
25       grating RG (see Fig. 16(B)) placed on the lower surface of wafer stage WST3 or WST4, via a gap between surface plate 14A and surface plate 14B or a light-transmitting section (e.g. an opening) formed at first section 14A<sub>1</sub> of surface plate 14A and first section 14B<sub>1</sub> of surface plate 14B and receiving

diffraction light from grating RG.

The measurement value of each of X head 79x and Y heads 79ya and 79yb included in third measurement head group 79H is supplied to main controller 20 (see Fig. 18). Main  
5 controller 20 computes the X-position, Y-position and  $\theta_z$  rotation of wafer stage WST3 or WST4 based on the measurement value of X head 79x, the average value of the measurement values of the pair of Y heads 79ya and 79yb, and the difference between the measurement values of Y heads 79ya and 79yb, respectively.

10 In this case, the separation distance in the Y-axis direction between third measurement head group 79H and each of first measurement head group 72 and second measurement head group 73 is set less than the width in the Y-axis direction of grating RG arranged on wafer stage WST3 or WST4. Therefore,  
15 simultaneously with heads 75x, 75ya and 75yb included in first measurement head group 72 irradiating grating RG with measurement beams, head 79x, 79ya and 79yb included in third measurement head group 79H can also irradiate grating RG with measurement beams. Likewise, simultaneously with heads 77x,  
20 77ya and 77yb included in second measurement head group 73 irradiating grating RG with measurement beams, head 75x, 75ya and 75yb included in third measurement head group 79H can also irradiate grating RG with measurement beams. Consequently, when wafer stages WST3 and WST4 move from measurement station  
25 300 to exposure station 200 across the scrub area, main controller 20 (see Fig. 18) can perform position control of wafer stages WST3 and WST4, using first and second measurement head groups 72 and 73 (stage position measuring system 70) and third measurement head group 79H (auxiliary stage position

measuring system 79) by switching them according to the Y-position of wafer stages WST3 and WST4.

Interferometer system 67A (see Fig. 18) measures positional information of wafer stage WST3 when wafer stage WST3 moves from exposure station 200 to measurement station 300 (or in a direction reverse thereto) passing through an area on the -X side (hereinafter, referred to as a first withdrawal area for the sake of convenience) excluding the scrum area on surface plate 14A.

As shown in Fig. 15, interferometer system 67A includes two interferometers 18YA<sub>1</sub> and 18YA<sub>2</sub> and four X interferometers 18XA<sub>1</sub>, 18XA<sub>2</sub>, 18XA<sub>3</sub> and 18XA<sub>4</sub>. Y interferometer 18YA<sub>2</sub> is placed on the +Y side of surface plate 14A. Y interferometer 18YA<sub>2</sub> irradiates reflection surface 17Y<sub>2</sub> with a measurement beam and receives a reflected beam from reflection surface 17Y<sub>2</sub>, thereby measuring the Y-position of reflection surface 17Y<sub>2</sub>, or more specifically, the Y-position of wafer stage WST3. Y interferometer 18YA<sub>1</sub> is placed on the -Y side of surface plate 14A. Similarly to Y interferometer 18YA<sub>2</sub>, for example, as shown in Figs. 25 and 26, Y interferometer 18YA<sub>1</sub> irradiates reflection surface 17Y<sub>1</sub> with a measurement beam and receives a reflected beam from reflection surface 17Y<sub>1</sub>, thereby measuring the Y-position of wafer stage WST3. Y interferometers 18YA<sub>1</sub> and 18YA<sub>2</sub> are mainly used when wafer stage WST3 is located in the -Y side half and the +Y side half in the first withdrawal area on surface plate 14A.

Meanwhile, X interferometers 18XA<sub>1</sub> to 18XA<sub>4</sub> are placed on the -X side of surface plate 14A, at a predetermined distance in the Y-axis direction. X interferometer 18XA<sub>3</sub> irradiates

reflection surface 17X with two measurement beams along an axis (measurement axis) parallel to the X-axis that is orthogonal to optical axis AX of projection optical system PL and reference axis LV, and receives reflected beams from reflection surface 17X, thereby measuring the X-position and  $\theta_z$  rotation (yawing amount) of wafer stage WST3. Likewise, X interferometers 18XA<sub>1</sub>, 18XA<sub>2</sub> and 18XA<sub>4</sub> also each irradiate reflection surface 17X with two measurement beams and receive reflected beams from reflection surface 17X, thereby measuring the X-position and  $\theta_z$  rotation (yawing amount) of wafer stage WST3. In this case, the distance between X interferometers 18XA<sub>1</sub> to 18XA<sub>4</sub> adjacent to each other in the Y-axis direction is set such that any of the X interferometers is surely opposed to reflection surface 17X of wafer stage WST3. Main controller 20 (see Fig. 18) constantly measures the X-position and  $\theta_z$  rotation (yawing amount) of wafer stage WST3 that moves within the first withdrawal area on surface plate 14A, using X interferometers 18XA<sub>1</sub> to 18XA<sub>4</sub> by switching them according to the Y-position of wafer stage WST3.

Similarly to interferometer system 67A, interferometer system 67B (see Fig. 18) measures positional information of wafer stage WST4 when wafer stage WST4 moves from exposure station 200 to measurement station 300 (or in a direction reverse thereto) passing through an area on the +X side (hereinafter, referred to as a second withdrawal area for the sake of convenience) excluding the scrum area on surface plate 14B.

As shown in Fig. 15, interferometer system 67B includes two interferometers 18YB<sub>1</sub> and 18YB<sub>2</sub> and four X interferometers



18XB<sub>1</sub>, 18XB<sub>2</sub>, 18XB<sub>3</sub> and 18XB<sub>4</sub>. Y interferometer 18YB<sub>1</sub> is placed on the -Y side of surface plate 14B. Y interferometer 18YB<sub>1</sub> irradiates reflection surface 17Y<sub>1</sub> with a measurement beam and receives a reflected beam from reflection surface 17Y<sub>1</sub>,  
5 thereby measuring the Y-position of reflection surface 17Y<sub>1</sub>, or more specifically, the Y-position of wafer stage WST4. Y interferometer 18YB<sub>2</sub> is placed on the +Y side of surface plate 14B. Similarly to Y interferometer 18YB<sub>1</sub>, for example, as shown in Figs. 30 to 32, Y interferometer 18YB<sub>2</sub> irradiates  
10 reflection surface 17Y<sub>2</sub> with a measurement beam and receives a reflected beam from reflection surface 17Y<sub>2</sub>, thereby measuring the Y-position of wafer stage WST4. Y interferometers 18YB<sub>1</sub> and 18YB<sub>2</sub> are mainly used when wafer stage WST4 is located on the -Y side and the +Y side within  
15 the second withdrawal area on surface plate 14B.

Meanwhile, X interferometers 18XB<sub>1</sub> to 18XB<sub>4</sub> are placed on the +X side of surface plate 14B, at a predetermined distance in the Y-axis direction. X interferometer 18XB<sub>3</sub> irradiates reflection surface 17X with two measurement beams along an  
20 axis (measurement axis) parallel to the X-axis that is orthogonal to optical axis AX of projection optical system PL and reference axis LV, and receives reflected beams from reflection surface 17X, thereby measuring the X-position and  $\theta_z$  rotation (yawing amount) of wafer stage WST4. Likewise,  
25 X interferometers 18XB<sub>1</sub>, 18XB<sub>2</sub> and 18XB<sub>4</sub> also each irradiate reflection surface 17X with two measurement beams and receive reflected beams from reflection surface 17X, thereby measuring the X-position and  $\theta_z$  rotation (yawing amount) of wafer stage WST4. In this case, the distance between X

.80.

interferometers 18XB<sub>1</sub> to 18XB<sub>4</sub> adjacent to each other in the Y-axis direction is set such that any of the X interferometers is surely opposed to reflection surface 17X of wafer stage WST4. Main controller 20 constantly measures the X-position and  $\theta_z$  rotation (yawing amount) of wafer stage WST4 that moves within the second withdrawal area on surface plate 14B, using X interferometers 18XB<sub>1</sub> to 18XB<sub>4</sub> by switching them according to the Y-position of wafer stage WST4.

As is obvious from Fig. 15, each of Y interferometers 18YA<sub>1</sub> and 18YA<sub>2</sub> and X interferometers 18XA<sub>1</sub> to 18XA<sub>4</sub> that configure interferometer system 67A is placed symmetric with each of Y interferometers 18YB<sub>1</sub> and 18YB<sub>2</sub> and X interferometers 18XB<sub>1</sub> to 18XB<sub>4</sub> that configure interferometer system 67B, with respect to reference axis LV.

Main controller 20 controls the position of each of wafer stages WST3 and WST4 by individually controlling stage driving systems 61A and 61B, based on the measurement values of interferometer systems 67A and 67B.

Fig. 18 shows a configuration of a control system of exposure apparatus 1000 of the present second embodiment. The control system is configured of main controller 20 as the central component. Main controller 20 includes a workstation(or a microcomputer) and the like, and performs overall control of the respective components of the exposure apparatus such as local liquid immersion device 8, surface plate driving systems 60A and 60B and stage driving systems 61A and 61B described earlier.

Next, a parallel exposure operation using the two wafer stages WST3 and WST4 is described with reference to Figs. 19

to 32. Note that during the exposure operation, main controller 20 controls liquid supply device 5 and liquid recovery device 6 as described earlier and the liquid immersion area is constantly formed directly under tip lens 191 of projection optical system PL by a constant quantity of liquid Lq being held.

Fig. 19 shows a state where exposure by a step-and-scan method is performed on wafer W mounted on wafer stage WST3 in exposure station 200, and in parallel with this exposure, wafer exchange is performed between a wafer carrier mechanism (not illustrated) and wafer stage WST4 at the second loading position.

As described earlier, the exposure operation by a step-and-scan method is performed by repeating an inter-shot movement (stepping between shots) operation of moving wafer stage WST3 to a scanning starting position (acceleration starting position) for exposure of each shot area on wafer W based on the results of wafer alignment and reticle alignment and the like that have been performed beforehand, and a scanning exposure operation of transferring a pattern formed on reticle R onto each shot area on wafer W by a scanning exposure method. The results of the wafer alignment are, for example, obtained from information that is acquired by converting the arrangement coordinate of each shot area on wafer W obtained by the Enhanced Global Alignment (EGA) into the coordinate with the second fiducial mark as a reference.

In exposure apparatus 1000 of the present embodiment, during a series of the exposure operations described above, main controller 20 measures the position of wafer stage WST3

using first measurement head group 72 of stage position measuring system 70 and controls the position of wafer stage WST3 (wafer W) based on this measurement result.

The wafer exchange is performed by unloading a wafer that  
5 has been exposed from wafer stage WST4 and loading a new wafer onto wafer stage WST4 by the wafer carrier mechanism that is not illustrated, when wafer stage WST4 is located at the second loading position described earlier.

During the wafer exchange described above, and after the  
10 wafer exchange, while wafer stage WST4 stops at the second loading position, main controller 20 executes reset (resetting of the origin) of second measurement head group 73 (i.e. encoders 55, 56 and 57 (and surface position measuring system 58) of stage position measuring system 70, prior to  
15 start of wafer alignment (and the other pre-processing measurements) with respect to the new wafer W.

When the wafer exchange (loading of the new wafer W) and the reset of stage position measuring system 70 (second measurement head group 73) have been completed, main  
20 controller 20 detects the second fiducial mark on measurement plate FM2 using primary alignment system AL1. Then, main controller 20 detects the position of the second fiducial mark with the index center of primary alignment system AL1 serving as a reference, and based on the detection result and the result  
25 of position measurement of wafer stage WST4 by stage position measuring system 70 (second measurement head group 73) at the time of the detection, computes the position coordinate of the second fiducial mark in an orthogonal coordinate system (alignment coordinate system) with reference axis La and

reference axis LV as coordinate axes.

Next, as shown in Fig. 20, main controller 20 performs the wafer alignment (EGA) while measuring the position coordinate of wafer stage WST4 in the alignment coordinate system using stage position measuring system 70 (second measurement head group 73). The details of the wafer alignment (EGA) are as described earlier. Then, based on the computation result of the position coordinate of the second fiducial mark and the results of the wafer alignment (EGA) described above, main controller 20 obtains the position coordinates of a plurality of shot areas on wafer W with the position of the second fiducial mark serving as the origin.

Normally, the above-described wafer exchange and wafer alignment sequence is completed earlier than the exposure sequence. Therefore, when the wafer alignment has been completed, main controller 20 drives wafer stage WST4 in the +Y direction to move wafer stage WST4 to the scrub area (the area between exposure station 200 and measurement station 300), as shown in Fig. 20. At this point in time, wafer stage WST4 goes out of a measurable range of stage position measuring system 70 (i.e. the measurement beams emitted from second measurement head group 73 move off from grating RG). Therefore, main controller 20 switches position measurement of wafer stage WST4 within the XY plane from the measurement using stage position measuring system 70 (second measurement head group 73) to the measurement using auxiliary stage position measuring system (third measurement head group) 79, and based on the measurement results, controls the position of wafer stage WST4. Then, main controller 20 causes wafer

stage WST4 to wait within the scrum area until exposure on wafer W on wafer stage WST3 is completed.

When the exposure on wafer W on wafer stage WST3 has been completed, main controller 20 starts to drive wafer stages WST3 and WST4 severally toward the scrum position shown in Fig. 22.

Then, in a state where wafer stages WST3 and WST4 have moved to the scrum position, wafer stage WST3 and wafer stage WST4 go into a scrum state where the end on the -Y side of wafer stage WST3 and the end on the +Y side of wafer stage WST4 are in proximity or in contact in the Y-axis direction. Accordingly, the upper surfaces of wafer stages WST3 and WST4 form a fully flat surface that is apparently integrated.

As shown in Fig. 22, while keeping the scrum state described above, main controller 20 drives wafer stage WST3 in the +Y direction as indicated by a black arrow based on the measurement result of stage position measuring system 70 (first measurement head group 72), and at the same time, drives wafer stage WST4 in the +Y direction as indicated by an outlined arrow based on the measurement result of auxiliary stage position measuring system (third measurement head group) 79. According to the movement of both stages WST3 and WST4, the liquid immersion area (liquid Lq) formed between tip lens 191 and wafer stage WST3 moves onto wafer stage WST4 as shown in Fig. 23.

On the movement described above, wafer stage WST3 goes out of a measurable range of stage position measuring system 70 (first measurement head group 72) into the first withdrawal area on surface plate 14A (i.e. the measurement beams emitted

from first measurement head group 72 move off from grating RG). Therefore, main controller 20 switches position measurement of wafer stage WST3 within the XY plane from the measurement using stage position measuring system 70 (first measurement head group 72) to the measurement using Y interferometer 18YA<sub>2</sub> and X interferometer 18XA<sub>4</sub> of interferometer system 67A, and based on the measurement results, controls the position of wafer stage WST3.

Further, wafer stage WST4 proceeds from the scrub area into exposure station 200. Accordingly, the measurement beams emitted from third measurement head group 79H that configures auxiliary stage position measuring system 79 move off from grating RG, and instead, the measurement beams emitted from first measurement head group 72 that configures stage position measuring system 70 are irradiated on grating RG. Therefore, main controller 20 switches position measurement of wafer stage WST4 within the XY plane from the measurement using auxiliary stage position measuring system (third measurement head group) 79 to the measurement using stage position measuring system 70 (first measurement head group 72), and based on the measurement results, controls the position of wafer stage WST4.

After the liquid immersion area (liquid Lq) has been moved onto wafer stage WST4, main controller 20 releases the scrub state of wafer stages WST3 and WST4. Then, main controller 20 moves wafer stage WST3 to the first loading position described previously through the first withdrawal area on surface plate 14A. In this case, while measuring the position of wafer stage WST3 using interferometer system 67A,

main controller 20 moves wafer stage WST3 in the -X direction along the +Y end of surface plate 14A as indicated by a black arrow in Fig. 23, and further, moves wafer stage WST3 in the -Y direction along the -X end of surface plate 14A as indicated by black arrows in Figs. 24 and 25, and furthermore, moves wafer stage WST3 in the +X direction along the -Y end of surface plate 14A as indicated by a black arrow in Fig. 26. At this point in time, as shown in Figs. 24 to 26, according to the Y-position of wafer stage WST3, the X interferometer used in the position measurement of wafer stage WST3 is sequentially switched to X interferometers 18XA<sub>4</sub>, 18XA<sub>3</sub>, 18XA<sub>2</sub>, and 18XA<sub>1</sub> and also the Y interferometer used in the position measurement of wafer stage WST3 is switched from Y interferometer 18YA<sub>2</sub> to Y interferometer 18YA<sub>1</sub>. Note that Fig. 25 shows a state where the interferometer is switched from Y interferometer 18YA<sub>2</sub> to Y interferometer 18YA<sub>1</sub>.

As shown in Fig. 26, after wafer stage WST3 has reached the first loading position, main controller 20 switches the position measurement of wafer stage WST within the XY plane from the measurement using interferometer system 67A to the measurement using stage position measuring system 70 (second measurement head group 73).

In parallel with the movement of wafer stage WST3 described above, main controller 20 drives wafer stage WST4, and as shown in Fig. 24, sets the position of measurement plate FM2 at directly under projection optical system PL. Then, the pair of first fiducial marks on measurement plate FM2 are detected using reticle alignment systems RA<sub>1</sub> and RA<sub>2</sub>, and the relative position of the projected images on the wafer of



reticle alignment marks on reticle R that correspond to the first fiducial marks is detected.

Based on the relative positional information detected as above and the positional information of the respective shot areas on wafer W with the second fiducial mark serving as a reference that has been previously obtained, main controller 20 computes the relative positional relation between the projection position of the pattern of reticle R (the projection center of projection optical system PL) and each of the shot areas on wafer W mounted on wafer stage WST4. While controlling the position of wafer stage WST4 based on the computation results, main controller 20 transfers the pattern of reticle R onto each shot area on wafer W mounted on wafer stage WST4 by a step-and-scan method, in a similar manner to the previously-described manner. Fig. 26 shows a state where the pattern of reticle R is transferred onto each shot area on wafer W in this manner.

In parallel with the above-described exposure operation on wafer W on wafer stage WST4, main controller 20 performs the wafer exchange between the wafer carrier mechanism (not illustrated) and wafer stage WST3 at the first loading position and mounts a new wafer W on wafer stage WST3.

Then, main controller 20 detects the second fiducial mark on measurement plate FM1 using primary alignment system AL1. Note that, prior to the detection of the second fiducial mark, main controller 20 executes reset (resetting of the origin) of second measurement head group 73 (i.e. encoders 55, 56 and 57 (and surface position measuring system 58)) of stage position measuring system 70, in a state where wafer

stage WST3 is located at the first loading position. After that, as shown in Fig. 27, main controller 20 performs wafer alignment (EGA) using alignment systems AL1 and AL2<sub>1</sub> to AL2<sub>4</sub>, which is similar to the above-described one, with respect to  
5 wafer W on wafer stage WST3, while controlling the position of wafer stage WST3.

When the wafer alignment (EGA) with respect to wafer W on wafer stage WST3 has been completed and also the exposure on wafer W on wafer stage WST4 has been completed, main  
10 controller 20 drives wafer stages WST3 and WST4 toward the scrum position as shown in Fig. 28. At this point in time, wafer stage WST3 moves out of the measurable range of stage position measuring system 70 (i.e. the measurement beams emitted from second measurement head group 73 move off from  
15 grating RG). Therefore, main controller 20 switches position measurement of wafer stage WST3 within the XY plan from the measurement using stage position measuring system 70 (second measurement head group 73) to the measurement using auxiliary stage position measuring system (third measurement head  
20 group) 79H, and based on the measurement result, controls the position of wafer stage WST3.

Then, in a state where wafer stage WST3 and WST4 have moved to the scrum position, wafer stage WST3 and wafer stage WST4 go into a scrum state of being in proximity or in contact  
25 in the Y-axis direction, as shown in Fig. 29. Different from the scrum described previously, however, the +Y end of wafer stages WST3 and the -Y end of wafer stage WST4 are in proximity or in contact. Accordingly, the upper surfaces of wafer stages WST3 and WST4 form a fully flat surface that is

apparently integrated.

While keeping the scrum state described above, main controller 20 drives wafer stage WST4 in the +Y direction as indicated by a black arrow in Fig. 29 based on the measurement  
5 result of stage position measuring system 70, and at the same time, drives wafer stage WST3 in the +Y direction as indicated by an outlined arrow in Fig. 29 based on the measurement result of auxiliary stage position measuring system (third measurement head group) 79H. According to the movement of  
10 both wafer stages WST3 and WST4, the liquid immersion area (liquid Lq) formed between tip lens 191 and wafer stage WST4 moves onto wafer stage WST3, as shown in Fig. 30.

On the movement described above, wafer stage WST4 goes out of a measurable range of stage position measuring system  
15 70 (first measurement head group 72) into the second withdrawal area on surface plate 14B (i.e. the measurement beams emitted from first measurement head group 72 move off from grating RG). Therefore, main controller 20 switches position measurement of wafer stage WST4 within the XY plane from the  
20 measurement using stage position measuring system 70 (first measurement head group 72) to the measurement using Y interferometer 18YB<sub>2</sub> and X interferometer 18XB<sub>4</sub> of interferometer system 67B, and based on the measurement results, controls the position of wafer stage WST4.

25 Further, wafer stage WST3 proceeds from the scrum area into exposure station 200. Accordingly, the measurement beams emitted from third measurement head group 79H that configures auxiliary stage position measuring system 79 move off from grating RG, and instead, the measurement beams emitted

from first measurement head group 72 that configure stage position measuring system 70 are irradiated on grating RG. Therefore, main controller 20 switches position measurement of wafer stage WST3 within the XY plane from the measurement using auxiliary stage position measuring system (third measurement head group) 79 to the measurement using stage position measuring system 70 (first measurement head group 72), and based on the measurement results, controls the position of wafer stage WST3.

After the liquid immersion area (liquid Lq) has been moved onto wafer stage WST3, main controller 20 releases the scrum state of wafer stages WST3 and WST4. Then, main controller 20 moves wafer stage WST4 to the second loading position through the withdrawal area on surface plate 14B. In this case, while measuring the position of wafer stage WST4 using interferometer system 67B, main controller 20 moves wafer stage WST4 in the +X direction along the +Y end of surface plate 14B as indicated by a black arrow in Fig. 30, and further, moves wafer stage WST4 in the -Y direction along the +X end of surface plate 14B as indicated by black arrows in Figs. 31 and 32, and furthermore, moves wafer stage WST4 in the -X direction along the -Y end of surface plate 14B as indicated by a black arrow in Fig. 32. Accordingly, wafer stage WST4 reaches the second loading position as shown in Fig. 19. At this point in time, as shown in Figs. 31, 32 and 19, according to the Y-position of wafer stage WST4, the X interferometer used in position measurement of wafer stage WST4 is sequentially switched to X interferometers 18XB<sub>4</sub>, 18XB<sub>3</sub>, 18XB<sub>2</sub>, and 18XB<sub>1</sub> and also the Y interferometer used in position

measurement of wafer stage WST4 is switched from Y  
interferometer 18YB<sub>2</sub> to Y interferometer 18YB<sub>1</sub>. Note that Fig.  
32 shows a state where the interferometers are switched from  
X interferometer 18XB<sub>3</sub> to X interferometer 18XB<sub>2</sub>, and from Y  
5 interferometer 18YB<sub>2</sub> to Y interferometer 18YB<sub>1</sub>.

As shown in Fig. 19, after wafer stage WST4 has reached  
the second loading position, main controller 20 switches the  
position measurement of wafer stage WST4 within the XY plane  
from the measurement using interferometer system 67B to the  
10 measurement using stage position measuring system 70 (second  
measurement head group 73).

When the movement of the liquid immersion area (liquid  
Lq) has been completed, main controller 20 starts exposure  
on wafer W on wafer stage WST3 in the procedure similar to  
15 the above-described one. In parallel with this exposure  
operation, main controller 20 exchanges wafer W that has been  
exposed on wafer stage WST4 with a new wafer W, and executes  
the wafer alignment with respect to the new wafer W, in the  
procedure similar to the above-described one.

20 Afterwards, main controller 20 repeatedly executes the  
parallel processing operation using wafer stages WST3 and WST4  
described above.

As described above, according to exposure apparatus 1000  
of the present second embodiment, the function effect  
25 equivalent to exposure apparatus 100 of the first embodiment  
described earlier can be obtained. Further, according to  
exposure apparatus 1000 of the present second embodiment,  
since not only first measurement head group 72 and second  
measurement head group 73 of stage position measuring system

70 but also third measurement head group 79H of auxiliary stage position measuring system 79 are placed at measurement bar 71, main controller 20 can accurately move wafer stages WST3 and WST4 between measurement station 300 and exposure station 200 through the scrum area, based on the measurement results of first measurement head group 72 and second measurement head group 73 of stage position measuring system 70 and third measurement head group 79H of auxiliary stage position measuring system 79. Further, according to exposure apparatus 1000, when the liquid immersion area (liquid Lq) formed on one of wafer stages WST3 and WST4 is moved onto the other of wafer stages WST3 and WST4, main controller 20 measures positional information of one of the wafer stages using first measurement head group 72 of stage position measuring system 70 and measures positional information of the other of the wafer stages or both of the wafer stages using auxiliary stage position measuring system 79 (third measurement head group 79H). Then, based on these measurement results, main controller 20 drives wafer stages WST3 and WST4 while maintaining the scrum state of making wafer stages WST3 and WST4 be in proximity (or be in contact) in the Y-axis direction, thereby moving the liquid immersion area (liquid Lq) formed on the one of the wafer stages onto the other of the wafer stages.

Incidentally, in the first and second embodiments above, while measurement bar 71 is configured of a beam-like member with the Y-axis direction serving as its longitudinal direction, measurement bar 71 can be configured of a beam-like member with the X-axis direction serving as its longitudinal

direction. In such a case, the measurement bar is respectively arranged within exposure station 200 (below projection unit PU) and within the measurement station 300 (below alignment device 99), and first and second measurement head groups 72 and 73 can be arranged at each of the measurement bars (to be first and second measurement bars), individually. For example, in the case where such first and second measurement bars are applied to the first embodiment described earlier, a head group similar to first measurement head group 72 (or the encoder heads included in first measurement head group 72) can be placed, on the first measurement bar, at an appropriate distance that is less than the width of grating RG in the X-axis direction. In this case, while measuring positional information of the two wafer stages with high precision using a plurality of head groups, main controller 20 causes the two wafer stages to be in proximity or in contact in the X-axis direction based on the measurement results, and moves the two wafer stages in the longitudinal direction (X-axis direction) of the first measurement bar while maintaining the state (X scrub state), and thereby can move the liquid immersion area (liquid Lq) formed on one of the wafer stages onto the other of the wafer stages.

Incidentally, while the exposure apparatuses in the first and second embodiments above each have two surface plates so as to correspond to two wafer stages, the number of the surface plates is not limited thereto, and for example, one surface plate or three or more surface plates can be employed. Further, the number of the wafer stages is not limited to two, but one wafer stage or three or more wafer stages can be

employed, and a measurement stage, for example, which has an aerial image measuring instrument, an uneven illuminance measuring instrument, an illuminance monitor, a wavefront aberration measuring instrument and the like, can be placed  
5 on the surface plate, which is disclosed in, for example, U.S. Patent Application Publication No. 2007/0201010.

Further, in the first and second embodiments above, while both ends of measurement bar 71 in the longitudinal direction are supported by main frame BD in a suspended manner,  
10 this is not intended to be limiting. For example, measurement bar 71 can be supported independently from main frame BD and a position sensor or the like can be provided so as to monitor and obtain the relative position between both of them. In this case, a drive mechanism for position adjustment can be arranged  
15 at the measurement bar. Further, the mid portion (which can be arranged at a plurality of positions) in the longitudinal direction of the measurement bar can be supported on the base board by an empty-weight canceller as disclosed in, for example, U.S. Patent Application Publication No. 2007/0201010.

20 Further, the motor to drive surface plates 14A and 14B on base board 12 is not limited to the planar motor by the electromagnetic force (Lorentz force) drive method, but for example, can be a planar motor (or a linear motor) by a variable magnetoresistance drive method. Further, the motor is not  
25 limited to the planar motor, but can be a voice coil motor that includes a mover fixed to the side surface of the surface plate and a stator fixed to the base board. Further, the surface plates can be supported on the base board via the empty-weight canceller as disclosed in, for example, U.S.



Patent Application Publication No. 2007/0201010 and the like. Further, the drive directions of the surface plates are not limited to the directions of three degrees of freedom, but for example, can be the directions of six degrees of freedom, only the Y-axis direction, or only the XY two-axial directions. In this case, the surface plates can be levitated above the base board by static gas bearings (e.g. air bearings) or the like. Further, in the case where the movement direction of the surface plates can be only the Y-axis direction, the surface plates can be mounted on, for example, a Y guide member arranged extending in the Y-axis direction so as to be movable in the Y-axis direction.

Incidentally, the position of the border line that separates the surface plate or the base member into a plurality of sections is not limited to the position as in the first and second embodiments above. While the border line is set to include reference axis LV and intersect optical axis AX in the embodiments above, the border line can be set at another position, for example, in the case where, if the boundary is located in the exposure station, the thrust of the planar motor at the portion where the boundary is located weakens.

Further, in the first and second embodiments above, while the grating is placed on the lower surface of the fine movement stage, or more specifically, the surface that is opposed to the upper surface of the surface plate, this is not intended to be limiting, and the main section of the fine movement stage is made up of a solid member that can transmit light, and the grating can be placed on the upper surface of the main section. In this case, since the distance between

the wafer and the grating is closer compared with the embodiments above, the Abbe error, which is caused by the difference in the Z-axis direction between the surface subject to exposure of the wafer that includes the exposure point and the reference surface (the placement surface of the grating) of position measurement of the fine movement stage by encoders 51, 52 and 53, can be reduced. Further, the grating can be formed on the back surface of the wafer holder. In this case, even if the wafer holder expands or the attachment position with respect to the fine movement stage shifts during exposure, the position of the wafer holder (wafer) can be measured according to the expansion or the shift.

Further, in the first and second embodiments above, while the case has been described as an example where the encoder system is equipped with the X head and the pair of Y heads, this is not intended to be limiting, and for example, one or two two-dimensional head(s) (2D head(s)) whose measurement directions are the two directions that are the X-axis direction and the Y-axis direction can be placed inside the measurement bar. In the case of arranging the two 2D heads, their detection points can be set at the two points that are spaced apart in the X-axis direction at the same distance from the exposure position as the center, on the grating. Further, while the case has been described where the number of the heads per head group is one X head and two Y heads, the number of the heads can further be increased. Moreover, first measurement head group 72 on the exposure station 300 side can further have a plurality of head groups. For example, on each of the sides (the four directions that are the +X, +Y,

-X and -Y directions) on the periphery of the head group placed at the position corresponding to the exposure position (a shot area being exposed on wafer W), another head group can be arranged. And, the position of the fine movement stage (wafer  
5 W) just before exposure of the shot area can be measured in a so-called read-ahead manner. Further, the configuration of the encoder system that configures fine movement stage position measuring system 70 is not limited to the one in the embodiment above and an arbitrary configuration can be  
10 employed. For example, a 3D head can also be used that is capable of measuring the positional information in each direction of the X-axis, the Y-axis and the Z-axis.

Further, in the first and second embodiments above, the measurement beams emitted from the encoder heads and the  
15 measurement beams emitted from the Z heads are irradiated on the gratings of the fine movement stages via a gap between the two surface plates or the light-transmitting section formed at each of the surface plates. In this case, as the light-transmitting section, holes each of which is slightly  
20 larger than a beam diameter of each of the measurement beams are formed at each of surface plates 14A and 14B taking the movement range of surface plate 14A or 14B as the counter mass into consideration, and the measurement beams can be made to pass through these multiple opening sections. Further, for  
25 example, it is also possible that pencil-type heads are used as the respective encoder heads and the respective Z heads, and opening sections in which these heads are inserted are formed at each of the surface plates.

Incidentally, in the embodiment above, the case has been described as an example where according to employment of the planar motors as coarse movement stage driving systems 62A and 62B that drive wafer stages WST1 and WST2, the guide surface  
5 (the surface that generates the force in the Z-axis direction) used on the movement of wafer stages WST1 and WST2 along the XY plane is formed by surface plates 14A and 14B that have the stator sections of the planar motors. However, the embodiment above is not limited thereto. Further, in the  
10 embodiment above, while the measurement surface (grating RG) is arranged on fine movement stages WFS1 and WFS2 and first measurement head group 72 (and second measurement head group 73) composed of the encoder heads (and the Z heads) is arranged at measurement bar 71, the embodiment above is not limited  
15 thereto. More specifically, reversely to the above-described case, the encoder heads (and the Z heads) can be arranged at fine movement stage WFS1 and the measurement surface (grating RG) can be formed on the measurement bar 71 side. Such a reverse placement can be applied to a stage device that has  
20 a configuration in which a magnetic levitated stage is combined with a so-called H-type stage, which is employed in, for example, an electron beam exposure apparatus, an EUV exposure apparatus or the like. In this stage device, since a stage is supported by a guide bar, a scale bar (which corresponds  
25 to the measurement bar on the surface of which a diffraction grating is formed) is placed below the stage so as to be opposed to the stage, and at least a part (such as an optical system) of an encoder head is placed on the lower surface of the stage that is opposed to the scale bar. In this case, the guide bar

configures the guide surface forming member. As a matter of course, another configuration can also be employed. The place where grating RG is arranged on the measurement bar 71 side can be, for example, measurement bar 71, or a plate of a nonmagnetic material or the like that is arranged on the entire surface or at least one surface on surface plate 14A (14B).

Further, in the embodiment above, while the case has been described where measurement bar 71 and main frame BD are integrated, this is not intended to be limiting, and measurement bar 71 and main frame BD can physically be separated. In such a case, a measurement device (e.g. an encoder and/or an interferometer, or the like) that measures the position (or displacement) of measurement bar 71 with respect to main frame BD (or a reference position), and an actuator or the like that adjusts the position of measurement bar 71 should be arranged, and based on the measurement result of the measurement device, main controller 20 and/or another controller should maintain the positional relation between main frame BD (and projection optical system PL) and measurement bar 71 in a predetermined relation (e.g. constant).

Further, a measurement system (sensor) that measures variation of measurement bar 71 with an optical method, a temperature sensor, a pressure sensor, an acceleration sensor for vibration measurement, and the like can be arranged at measurement bar 71. Further, a distortion sensor and/or a displacement sensor and the like to measure variation of measurement bar 71 can be arranged. Then, it is also possible to correct the positional information obtained by fine

movement stage position measuring system 70 and/or coarse movement stage position measuring systems 68A and 68B, using the values obtained by these sensors.

Further, in each of the embodiments above, while the case  
5 has been described where the present invention is applied to stage device (wafer stages) 50 of the exposure apparatus, this is not intended to be limiting, and the present invention can also be applied to reticle stage RST.

Incidentally, in the embodiment above, grating RG can  
10 be covered with a protective member, e.g. a cover glass, so as to be protected. The cover glass can be arranged to cover the substantially entire surface of the lower surface of main section 80, or can be arranged to cover only a part of the lower surface of main section 80 that includes grating RG.  
15 Further, while a plate-shaped protective member is desirable because the thickness enough to protect grating RG is required, a thin film-shaped protective member can also be used depending on the material.

Besides, it is also possible that a transparent plate,  
20 on one surface of which grating RG is fixed or formed, has the other surface that is placed in contact with or in proximity to the back surface of the wafer holder and a protective member (cover glass) is arranged on the one surface side of the transparent plate, or the one surface of the transparent plate  
25 on which grating RG is fixed or formed is placed in contact with or in proximity to the back surface of the wafer holder without arranging the protective member (cover glass).

Especially in the former case, grating RG can be fixed or formed on an opaque member such as ceramics instead of the transparent

plate, or grating RG can be fixed or formed on the back surface of the wafer holder. In the latter case, even if the wafer holder expands or the attachment position with respect to the fine movement stage shifts during exposure, the position of the wafer holder (wafer) can be measured according to the expansion or the shift. Or, it is also possible that the wafer holder and grating RG are merely held by the conventional fine movement stage. Further, it is also possible that the wafer holder is formed by a solid glass member, and grating RG is placed on the upper surface (wafer mounting surface) of the glass member.

Incidentally, in the embodiment above, while the case has been described as an example where the wafer stage is a coarse/fine movement stage that is a combination of the coarse movement stage and the fine movement stage, this is not intended to be limiting. Further, in the embodiment above, while fine movement stages WFS1 and WFS2 can be driven in all the directions of six degrees of freedom, this is not intended to be limiting, and the fine movement stages should be moved at least within the two-dimensional plane parallel to the XY plane. Moreover, fine movement stages WFS1 and WFS2 can be supported in a contact manner by coarse movement stages WCS1 and WCS2. Consequently, the fine movement stage driving system to drive fine movement stage WFS1 or WFS2 with respect to coarse movement stage WCS1 or WCS2 can be a combination of a rotary motor and a ball screw (or a feed screw).

Incidentally, the fine movement stage position measuring system can be configured such that the position measurement can be performed in the entire area of the movement

range of the wafer stages. In such a case, the coarse movement stage position measuring systems become unnecessary.

Incidentally, the wafer used in the exposure apparatus of the embodiment above can be any one of wafers with various sizes, such as a 450-mm wafer or a 300-mm wafer.

Incidentally, in each of the embodiments above, while the case has been described where the exposure apparatus is the liquid immersion type exposure apparatus, this is not intended to be limiting. The embodiment above can suitably be applied to a dry type exposure apparatus that performs exposure of wafer W without liquid (water).

Incidentally, in the first and second embodiments above, while the case has been described where the exposure apparatus is a scanning stepper, this is not intended to be limiting, and each of the embodiments above can also be applied to a static exposure apparatus such as a stepper. Even in the stepper or the like, occurrence of position measurement error caused by air fluctuation can be reduced to almost zero by measuring the position of a stage on which an object that is subject to exposure is mounted using an encoder. Therefore, it becomes possible to set the position of the stage with high precision based on the measurement values of the encoder, and as a consequence, high-precision transfer of a reticle pattern onto the object can be performed. Further, each of the embodiments above can also be applied to a reduced projection exposure apparatus by a step-and-stitch method that synthesizes a shot area and a shot area.

Further, the magnification of the projection optical system in the exposure apparatus in the first and second



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embodiments above is not only a reduction system, but also can be either an equal magnifying system or a magnifying system, and the projection optical system is not only a dioptric system, but also can be either a catoptric system or a catadioptric system, and in addition, the projected image can be either an inverted image or an erected image.

Further, illumination light IL is not limited to ArF excimer laser light (with a wavelength of 193 nm), but can be ultraviolet light such as KrF excimer laser light (with a wavelength of 248 nm), or vacuum ultraviolet light such as F<sub>2</sub> laser light (with a wavelength of 157 nm). As disclosed in, for example, U.S. Patent No. 7,023,610, a harmonic wave, which is obtained by amplifying a single-wavelength laser beam in the infrared or visible range emitted by a DFB semiconductor laser or fiber laser with a fiber amplifier doped with, for example, erbium (or both erbium and ytterbium), and by converting the wavelength into ultraviolet light using a nonlinear optical crystal, can also be used as vacuum ultraviolet light.

Further, in the first and second embodiments above, illumination light IL of the exposure apparatus is not limited to the light having a wavelength more than or equal to 100nm, and it is needless to say that the light having a wavelength less than 100nm can be used. For example, the each of the embodiments above can be applied to an EUV (Extreme Ultraviolet) exposure apparatus that uses EUV light in a soft X-ray range (e.g. a wavelength range from 5 to 15 nm). In addition, the each of the embodiments above can also be applied to an exposure apparatus that uses charged particle beams such

as an electron beam or an ion beam.

Further, in the first and second embodiments above, a light transmissive type mask (reticle) is used, which is obtained by forming a predetermined light-shielding pattern (or a phase pattern or a light-attenuation pattern) on a light-transmitting substrate, but instead of this reticle, as disclosed in, for example, U.S. Patent No. 6,778,257, an electron mask (which is also called a variable shaped mask, an active mask or an image generator, and includes, for example, a DMD (Digital Micromirror Device) that is a type of a non-emission type image display element (spatial light modulator) or the like) on which a light-transmitting pattern, a reflection pattern, or an emission pattern is formed according to electronic data of the pattern that is to be exposed can also be used. In the case of using such a variable shaped mask, a stage on which a wafer, a glass plate or the like is mounted is scanned relative to the variable shaped mask, and therefore the equivalent effect to the embodiments above can be obtained by measuring the position of this stage using an encoder system.

Further, as disclosed in, for example, PCT International Publication No. 2001/035168, the each of the embodiments above can also be applied to an exposure apparatus (a lithography system) in which line-and-space patterns are formed on wafer W by forming interference fringes on wafer W.

Moreover, the each of the embodiments above can also be applied to an exposure apparatus that synthesizes two reticle patterns on a wafer via a projection optical system and substantially simultaneously performs double exposure of one

shot area on the wafer by one scanning exposure, as disclosed in, for example, U.S. Patent No. 6,611,316.

Incidentally, an object on which a pattern is to be formed (an object subject to exposure on which an energy beam is irradiated) in the first and second embodiments above is not limited to a wafer, but may be another object such as a glass plate, a ceramic substrate, a film member, or a mask blank.

The usage of the exposure apparatus is not limited to the exposure apparatus used for manufacturing semiconductor devices, but the present invention can be widely applied also to, for example, an exposure apparatus for manufacturing liquid crystal display elements in which a liquid crystal display element pattern is transferred onto a rectangular glass plate, and to an exposure apparatus for manufacturing organic EL, thin-film magnetic heads, imaging devices (such as CCDs), micromachines, DNA chips or the like. Further, the each of the embodiments above can also be applied to an exposure apparatus that transfers a circuit pattern onto a glass substrate, a silicon wafer or the like not only when producing microdevices such as semiconductor devices, but also when producing a reticle or a mask used in an exposure apparatus such as an optical exposure apparatus, an EUV exposure apparatus, an X-ray exposure apparatus, and an electron beam exposure apparatus.

Incidentally, the disclosures of all publications, the PCT International Publications, the U.S. Patent Application Publications and the U.S. Patents that are cited in the description so far related to exposure apparatuses and the

like are each incorporated herein by reference.

Electron devices such as semiconductor devices are manufactured through the following steps: a step where the function/performance design of a device is performed; a step  
5 where a reticle based on the design step is manufactured; a step where a wafer is manufactured using a silicon material; a lithography step where a pattern of a mask (the reticle) is transferred onto the wafer with the exposure apparatus (pattern formation apparatus) of the embodiments described  
10 earlier and the exposure method thereof; a development step where the exposed wafer is developed; an etching step where an exposed member of an area other than an area where resist remains is removed by etching; a resist removing step where the resist that is no longer necessary when the etching is  
15 completed is removed; a device assembly step (including a dicing process, a bonding process, and a packaging process); an inspection step; and the like. In this case, in the lithography step, the exposure method described earlier is executed using the exposure apparatus of the embodiments above  
20 and device patterns are formed on the wafer, and therefore, the devices with high integration degree can be manufactured with high productivity.

### **Industrial Applicability**

25 As described above, the exposure apparatus of the present invention is suitable for exposing an object with an energy beam. Further, the device manufacturing method of the present invention is suitable for manufacturing electron devices.

**Claims**

1. An exposure apparatus that exposes an object with an energy beam via an optical system and a liquid, the apparatus  
5 comprising:

a first and a second movable bodies which independently move on a guide surface parallel to a two-dimensional plane while each holding the object, and at each of which a measurement surface parallel to the two-dimensional plane is  
10 arranged;

a guide surface forming member that forms the guide surface;

a liquid supply device that supplies the liquid to a space between the optical system and the object held by the  
15 first or second movable body;

a first measurement system that irradiates the measurement surface of the first or second movable body that moves within a first area, with a measurement beam from a side opposite to the optical system with respect to the guide  
20 surface forming member, and receives light from the measurement surface, thereby obtaining positional information of the first or second movable body; and

a second measurement system that, when one of the first and second movable bodies located within the first area moves  
25 in proximity to the other of the first and second movable bodies and thereby the liquid supplied on the one of the movable bodies moves onto the other of the movable bodies, obtains at least positional information of the other of the movable bodies.

2. The exposure apparatus according to claim 1, wherein  
the first measurement system irradiates the measurement  
beam on a point on the measurement surface that corresponds  
to an exposure position that is a center of an irradiation  
5 area of the energy beam irradiated on the object.

3. The exposure apparatus according to one of claims  
1 and 2, wherein  
the second measurement system irradiates the  
10 measurement surface of the other of the movable bodies that  
moves within an overlapping area at least a part of which  
overlaps the first area within the two-dimensional plane, with  
a measurement beam from a side opposite to the optical system  
with respect to the guide surface forming member, and receives  
15 light from the measurement surface, thereby obtaining  
positional information of the other of the movable bodies.

4. The exposure apparatus according to claim 3, wherein  
the second measurement system, together with the first  
20 measurement system, irradiates the measurement beam on the  
measurement surfaces of the first and second movable bodies  
located within the at least a part of the overlapping area.

5. The exposure apparatus according to any one of claims  
25 1 to 4, wherein  
the second measurement system includes an  
interferometer system that obtains positional information of  
the first and second movable bodies by irradiating a  
measurement beam on reflection surfaces that are respectively

arranged at the first and second movable bodies and receiving light from the reflection surfaces.

6. The exposure apparatus according to any one of claims 1 to 5, further comprising:

a mark detecting system that detects a plurality of marks arranged on the object held by the first or second movable body within a second area that is away from the first area.

7. The exposure apparatus according to claim 6, wherein the first and second movable bodies move between the first and second areas passing through a measurement area where the second measurement system obtains the positional information of the first and second movable bodies.

15

8. The exposure apparatus according to one of claims 6 and 7, further comprising:

a third measurement system that obtains positional information of the first or second movable body by irradiating the measurement surface of the first or second movable body that moves within the second area, with a measurement beam from a side opposite to the optical system with respect to the guide surface forming member, and receiving light from the measurement surface.

25

9. The exposure apparatus according to claim 8, wherein the third measurement system irradiates the measurement beam on a point on the measurement surface that corresponds to a detection center of the mark detecting system.

10. The exposure apparatus according to one of claims  
8 and 9, wherein

at least a part of the third measurement system is  
5 installed at a second support member supported by a first  
support member that supports the optical system.

11. The exposure apparatus according to claim 10,  
wherein

10 the guide surface forming member is a surface plate which  
is placed on the optical system side of the second support  
member so as to be opposed to the movable body and which has  
the guide surface formed on one surface thereof on a side  
opposed to the movable body, and

15 the second support member is supported by the surface  
plate without being in contact with the surface plate.

12. The exposure apparatus according to one of claims  
10 and 11, wherein

20 at least a part of the first measurement system is placed  
at the second support member.

13. The exposure apparatus according to any one of  
claims 10 to 12, wherein

25 at least a part of the second measurement system is  
placed at the second support member.

14. The exposure apparatus according to any one of  
claims 1 to 13, wherein



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at least one of the first and second movable bodies includes a first movable body member that is movable on the guide surface while holding the object, and a second movable body member that is placed on an outer side of the first movable  
5 body member and is movable on the guide surface while supporting the first movable body member relatively movable, and

the first and second movable body members are in proximity to each other when the first and second movable  
10 bodies are in proximity.

15. The exposure apparatus according to claim 14, further comprising:

a relative drive system that drives the first movable  
15 body member relative to the second movable body member.

16. The exposure apparatus according to one of claims 14 and 15, further comprising:

a relative position measuring system that obtains  
20 relative positional information between the first movable body member and the second movable body member.

17. An exposure apparatus that exposes an object with an energy beam via an optical system, the apparatus comprising:

25 a first and a second movable bodies which independently move on a guide surface parallel to a two-dimensional plane while each holding the object, and at each of which a measurement surface parallel to the two-dimensional plane is arranged;

a guide surface forming member that forms the guide surface;

a first measurement system that irradiates the measurement surface of the first or second movable body that  
5 moves within a first area, with a measurement beam from a side opposite to the optical system with respect to the guide surface forming member, and receives light from the measurement surface, thereby obtaining positional information of the first or second movable body;

10 a mark detecting system that detects a plurality of marks formed on the object held by the first or second movable body within a second area that is away from the first area;

a second measurement system that obtains positional information of the first and second movable bodies that move  
15 within a third area that includes an area between the first and second areas; and

a third measurement system that irradiates the measurement surface of the first or second movable body that moves within the second area, with a measurement beam from  
20 a side opposite to the optical system with respect to the guide surface forming member, and receives light from the measurement surface, thereby obtaining positional information of the first or second movable body.

25 18. The exposure apparatus according to claim 17, wherein,

the first and second movable bodies move between the first and second areas passing through the third area.

19. The exposure apparatus according to one of claims 17 and 18, wherein

the first measurement system irradiates the measurement beam on a point on the measurement surface that corresponds to an exposure position that is a center of an irradiation area of the energy beam irradiated on the object.

20. The exposure apparatus according to any one of claims 17 to 19, wherein

the third measurement system irradiates the measurement beam on a point on the measurement surface that corresponds to a detection center of the mark detecting system.

21. The exposure apparatus according to any one of claims 17 to 20, wherein

at least a part of the first measurement system is placed at a second support member supported by a first support member that supports the optical system.

22. The exposure apparatus according to claim 21, wherein

at least a part of the third measurement system is placed at the second support member.

23. The exposure apparatus according to one of claims 21 and 22, wherein

the guide surface forming member is a surface plate which is placed on the optical system side of the second support member so as to be opposed to the movable body and which has

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the guide surface formed on one surface thereof on a side opposed to the movable body, and

the second support member is supported by the surface plate without being in contact with the surface plate.

5

24. The exposure apparatus according to claim 23, wherein

the second measurement system placed below the surface plate irradiates a measurement beam on the measurement surface of the first or second movable body that moves within the third area and receives light from the measurement surface, via the surface plate, thereby obtaining positional information of the first or second movable body.

10

25. The exposure apparatus according to any one of claims 17 to 24, wherein

the second measurement system includes an interferometer system that irradiates a measurement beam on reflection surfaces that are respectively arranged at the first and second movable bodies that move within the third area and receives light from the reflection surfaces, thereby obtaining positional information of the first and second movable bodies.

15

26. The exposure apparatus according to any one of claims 17 to 25, further comprising:

a liquid supply device that supplies the liquid to a space between the optical system and the object held by the first or second movable body within the first area where the

exposure is performed.

27. The exposure apparatus according to claim 26,  
wherein

5       when one of the first and second movable bodies located  
within the first area moves in proximity to the other of the  
first and second movable bodies located within the third area  
and thereby the liquid supplied on the one of the movable bodies  
moves onto the other of the movable bodies, the second  
10   measurement system obtains at least positional information  
of the other of the movable bodies.

28. The exposure apparatus according to one of claims  
26 and 27, wherein

15       at least one of the first and second movable bodies  
includes a first movable body member that is movable on the  
guide surface while holding the object, and a second movable  
body member that is placed on an outer side of the first movable  
body member and is movable on the guide surface while  
20   supporting the first movable body member relatively movable,  
and

the first and second movable body members are in  
proximity to each other when the first and second movable  
bodies are in proximity.

25

29. The exposure apparatus according to claim 28,  
further comprising:

a relative drive system that drives the first movable  
body member relative to the second movable body member.

30. The exposure apparatus according to one of claims 28 and 29, further comprising:

5 a relative position measuring system that obtains relative positional information between the first and second movable body members.

31. An exposure apparatus that exposes an object with an energy beam via an optical system and a liquid, the apparatus 10 comprising:

a first and a second movable bodies each of which includes a first movable body member that is movable on a guide surface parallel to a two-dimensional plane while holding the object, and a second movable body member that is placed on 15 an outer side of the first movable body member, supports the first movable body member relatively movable, is movable on the guide surface, and has a measurement surface parallel to the two-dimensional plane arranged thereon;

a liquid supply device that supplies the liquid to a 20 space between the optical system and the object held by the first or second movable body;

a first measurement system that irradiates the measurement surface of the first or second movable body that moves within a first area, with a measurement beam from a side 25 opposite to the optical system, and receives light from the measurement surface, thereby obtaining positional information of the first or second movable body; and

a second measurement system that, when the liquid supplied on one of the first and second movable bodies located

within the first area is moved onto the other of the first and second movable bodies, obtains at least positional information of the other of the movable bodies.

5        32. The exposure apparatus according to claim 31, further comprising:

          a control system that causes the first and second movable body members, which the first and second movable bodies each have, to be in proximity and also causes the first and second  
10 movable bodies to be in proximity, and moves the first and second movable bodies while maintaining the proximity state, using measurement results of the first measurement system and the second measurement system, wherein

          when moving the liquid between the first and second  
15 movable bodies, the control system causes the first and second movable body members, which the first and second movable bodies each have, to be in proximity in one axial direction within the two-dimensional plane and also causes the first and second movable bodies to be in proximity, and moves the first and  
20 second movable bodies in the one axial direction while maintaining the proximity state.

          33. The exposure apparatus according to one of claims 31 and 32, further comprising:

25        a relative drive system that drives the first movable body member relative to the second movable body member.

          34. The exposure apparatus according to one of claims 32 and 33, further comprising:

a relative position measuring system that obtains relative positional information between the first and second movable body members, wherein

the control system relatively moves the second movable  
5 body member with respect to the first movable body member based on a measurement result of the relative position measuring system.

35. The exposure apparatus according to any one of  
10 claims 31 to 34, wherein

the second measurement system irradiates the measurement surface of the first or second movable body that moves within an overlapping area, at least a part of which overlaps the first area, with a measurement beam from a side  
15 opposite to the optical system, and receives light from the measurement surface, thereby obtaining positional information of the first or second movable body.

36. The exposure apparatus according to claim 35,  
20 wherein

the second measurement system, together with the first measurement system, irradiates the measurement beam on the measurement surface of the first or second movable body located within the partly overlapping area.

25

37. The exposure apparatus according to any one of claims 31 to 36, wherein

the second measurement system includes an interferometer system that obtains positional information of



the first and second movable bodies by irradiating a measurement beam on reflection surfaces that are respectively arranged at the first and second movable bodies and receiving light from the reflection surfaces.

5

38. The exposure apparatus according to any one of claims 31 to 37, further comprising:

a mark detecting system that detects a plurality of marks formed on the object held by the first or second movable body within a second area that is away from the first area.

10

39. The exposure apparatus according to claim 38, wherein,

the first and second movable bodies move between the first and second areas passing through a measurement area where the second measurement system obtains the positional information of the first and second movable bodies.

15

40. The exposure apparatus according to one of claims 38 and 39, further comprising:

a third measurement system that irradiates the measurement surface of the first or second movable body that moves within the second area, with a measurement beam from a side opposite to the optical system, and receives light from the measurement surface, thereby obtaining positional information of the first or second movable body.

25

41. The exposure apparatus according to any one of claims 1 to 40, wherein

the measurement surface is arranged on a first surface of each of the first and second movable bodies, the first surface being opposed to the guide surface and parallel to the two-dimensional plane, and

5       the object is mounted on a second surface of each of the first and second movable bodies, the second surface being on a side opposite to the first surface and parallel to the two-dimensional plane.

10       42. The exposure apparatus according to any one of claims 1 to 41, wherein

on the measurement surface, a grating whose periodic direction is in a direction parallel to the two-dimensional plane is arranged, and

15       the first measurement system receives diffraction light from the measurement surface.

43. An exposure apparatus that exposes an object with an energy beam via an optical system and a liquid, the apparatus  
20 comprising:

a first and a second movable bodies each of which includes a first movable body member that is movable on a guide surface parallel to a two-dimensional plane while holding the object, and a second movable body member that is placed on  
25 an outer side of the first movable body member, supports the first movable body member relatively movable, and is movable on the guide surface;

a liquid supply device that supplies the liquid to a space between the optical system and the object held by the

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first or second movable body; and

a control system that moves the liquid supplied on one of the movable bodies onto the other of the movable bodies by driving the first and second movable bodies to cause the first and second movable body members, which the first and second movable bodies each have, to be in proximity in one axial direction within the two-dimensional plane and also cause the second movable body member of the first movable body and the second movable body member of the second movable body to be in proximity, and moving the first and second movable bodies in the one axial direction while maintaining the proximity state.

44. The exposure apparatus according to claim 43, wherein

a surface of the object and an upper surface of the second movable body member of each of the first and second movable bodies form a single plane parallel to the two-dimensional plane.

20

45. The exposure apparatus according to one of claims 43 and 44, wherein

the upper surface of second movable body member has liquid repellency.

25

46. The exposure apparatus according to any one of claims 43 to 45, wherein

the first movable body member has a flush plane forming section whose surface forms a plane flush with the surface

of the object, on an outer side of an area where the object is mounted.

47. The exposure apparatus according to claim 46,  
5 wherein  
an upper surface of the flush plane forming section has liquid repellency.

48. The exposure apparatus according to any one of  
10 claims 43 to 47, further comprising:  
a relative drive system that drives the first movable body member relative to the second movable body member.

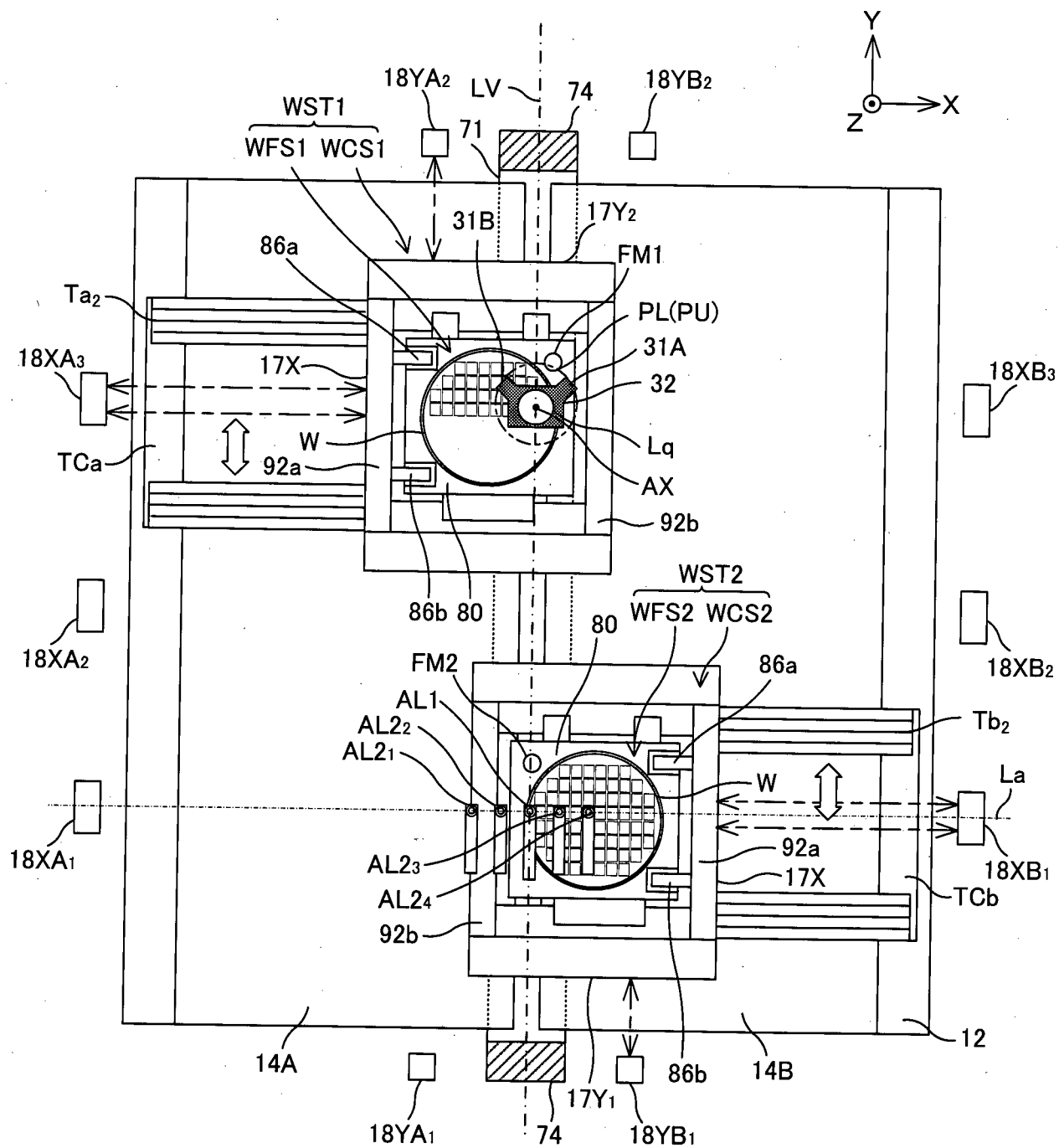
49. The exposure apparatus according to any one of  
15 claims 43 to 48, further comprising:  
a relative position measuring system that obtains relative positional information between the first movable body member and the second movable body member, wherein  
the control system relatively moves the second movable  
20 body member with respect to the first movable body member using a measurement result of the relative position measuring system.

50. The exposure apparatus according to any one of  
25 claims 43 to 49, wherein  
each of the second movable body members included in the first and second movable bodies is formed into a frame shape that encloses four sides of the first movable body member supported by the each of the second movable body members.

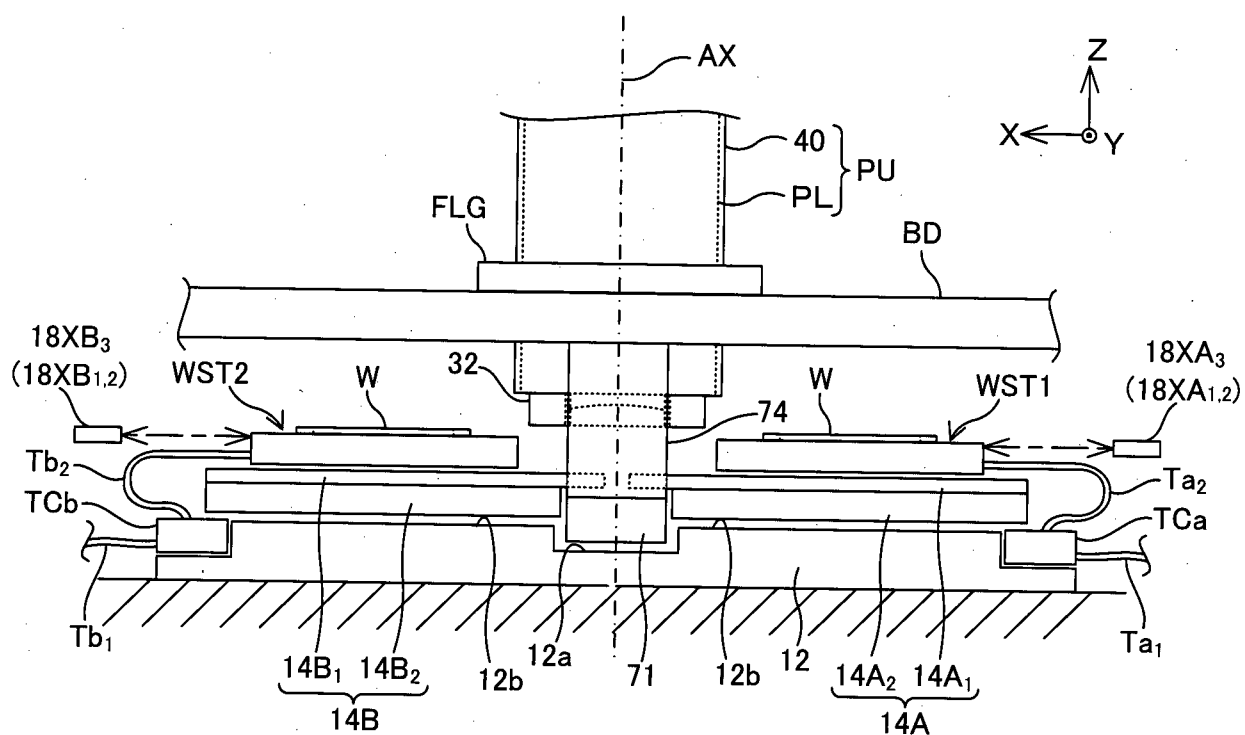
51. A device manufacturing method, comprising:  
exposing an object using the exposure apparatus  
according to any one of claims 1 to 50; and  
5 developing the exposed object.



*Fig. 2*



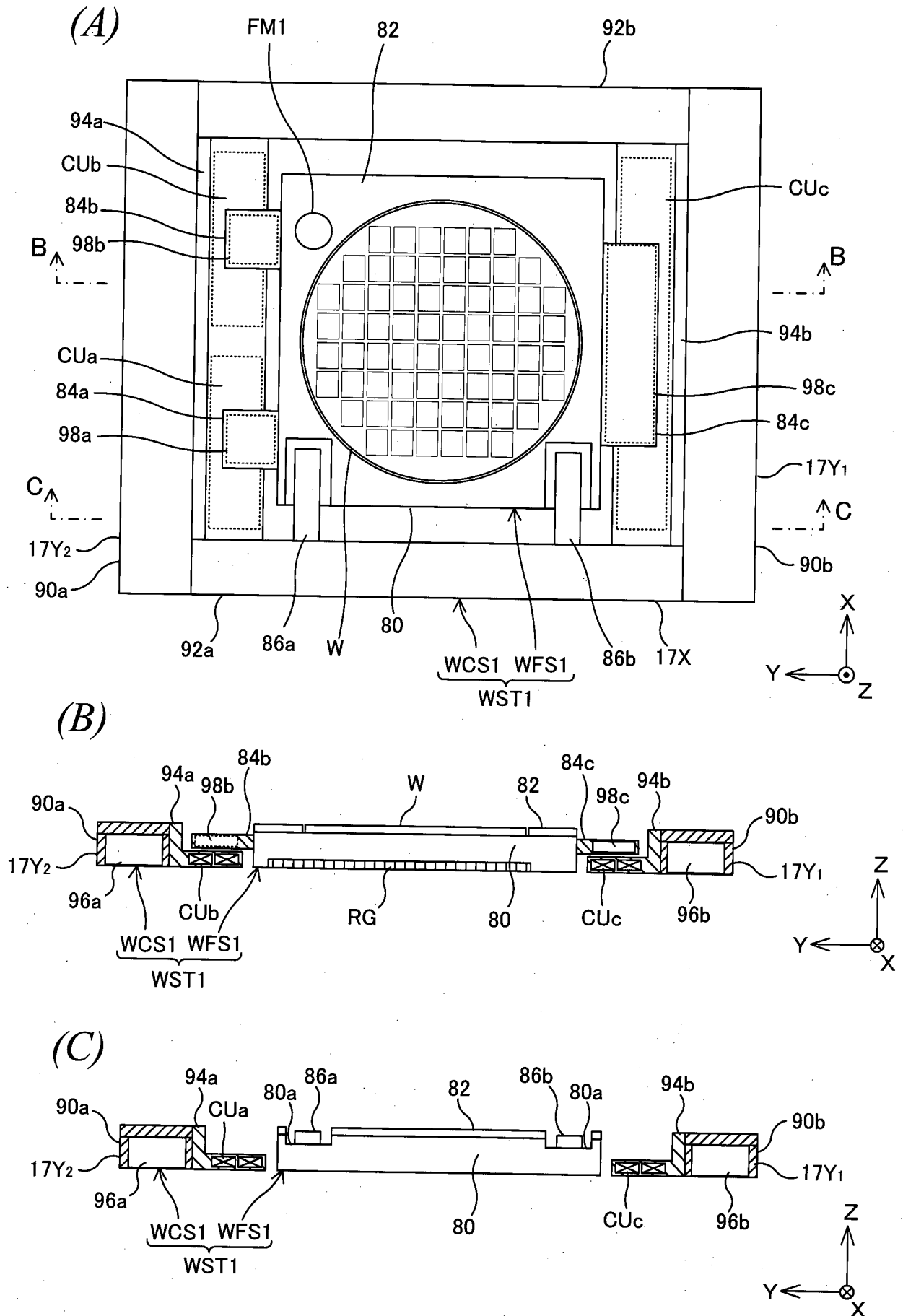
*Fig. 3*





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Fig. 4



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Fig. 5

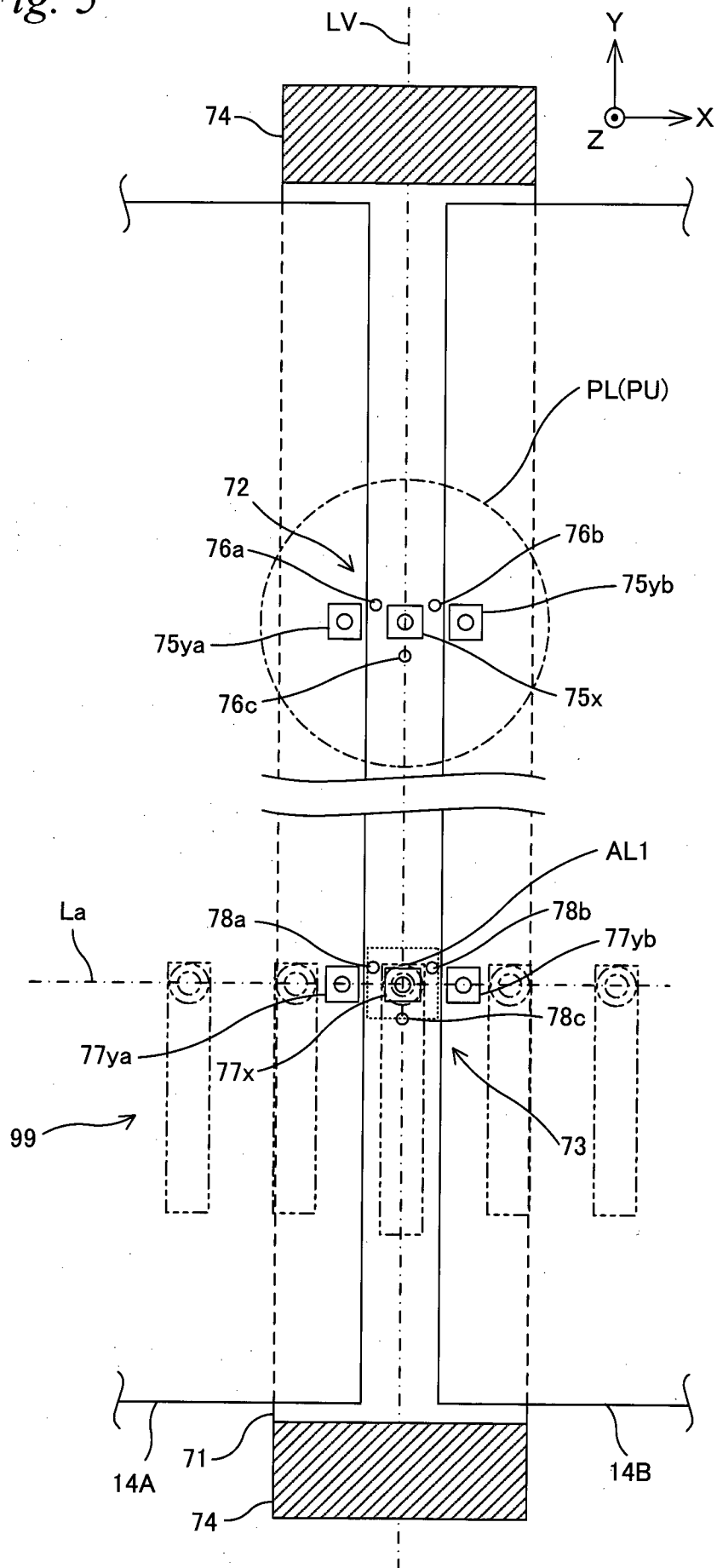


Fig. 6

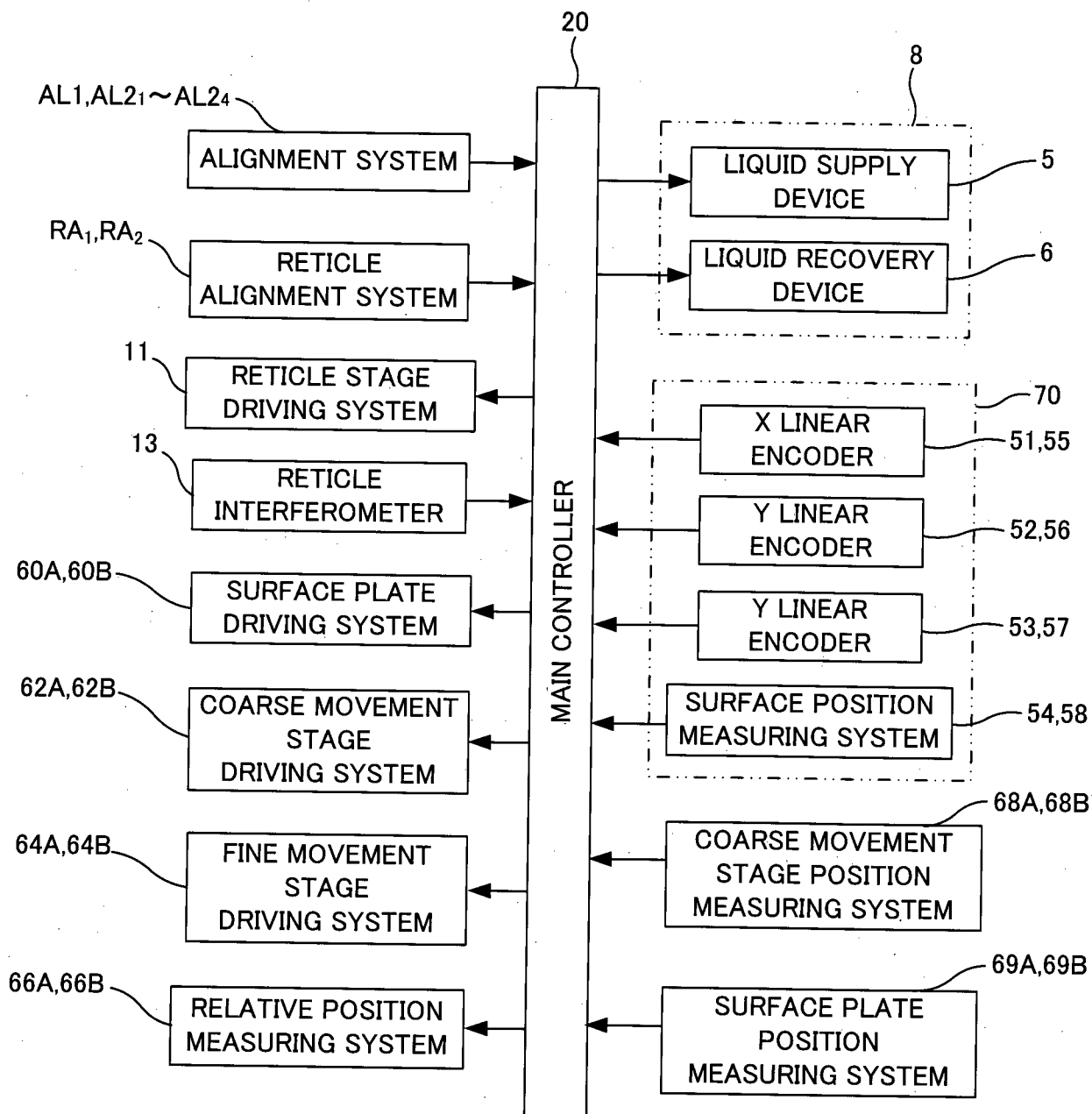
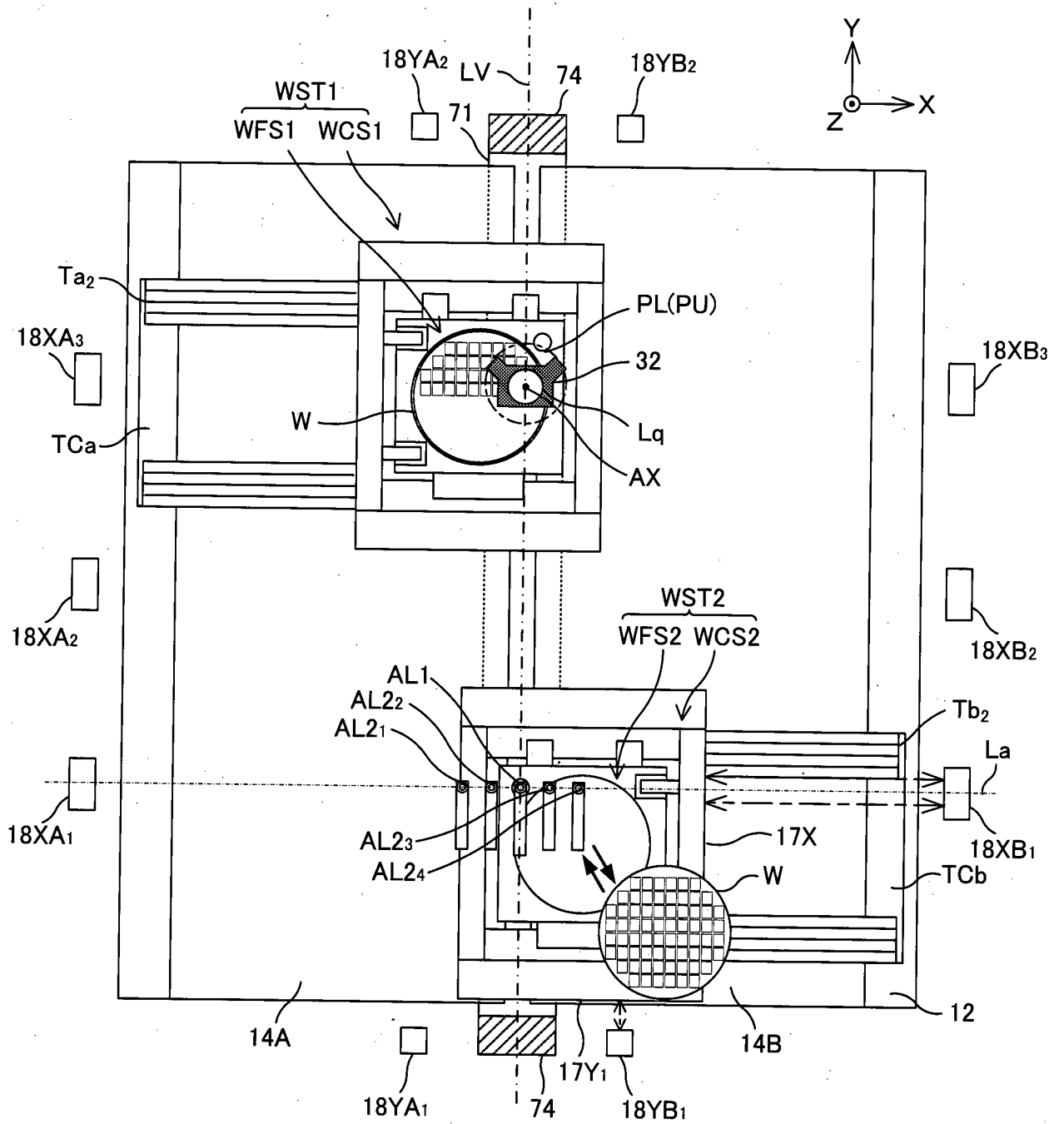
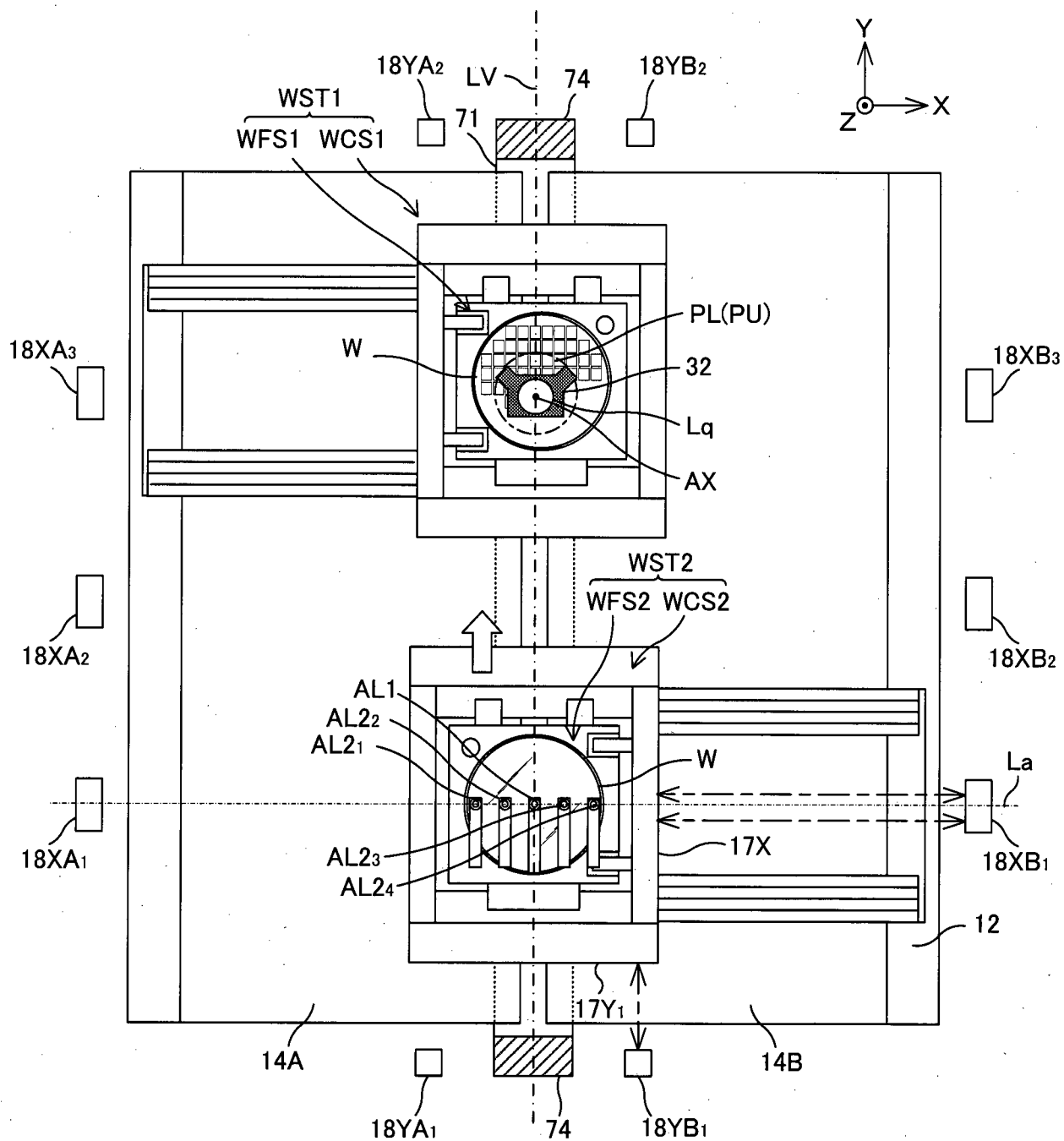


Fig. 7



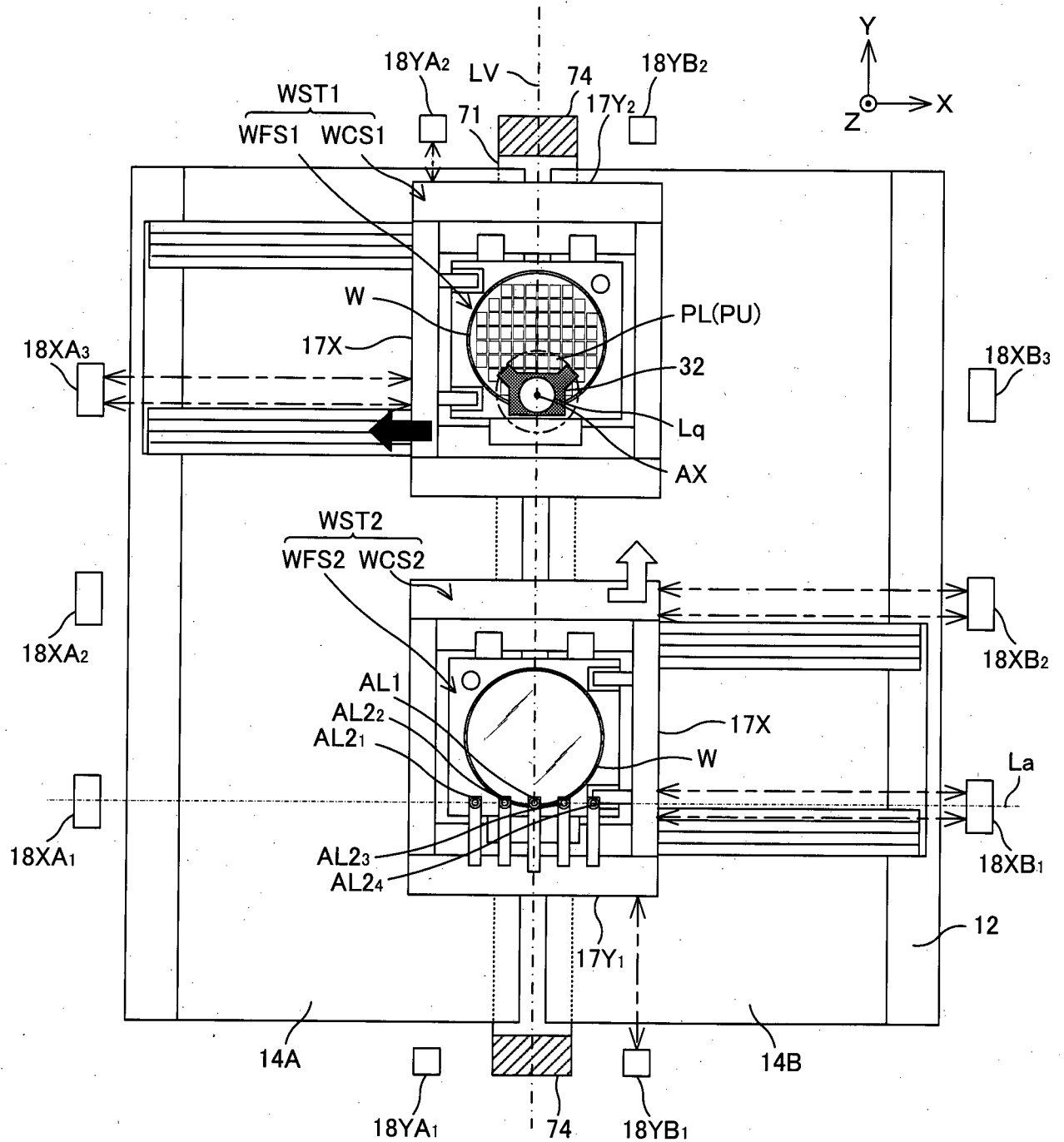
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Fig. 8



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Fig. 9



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Fig. 10

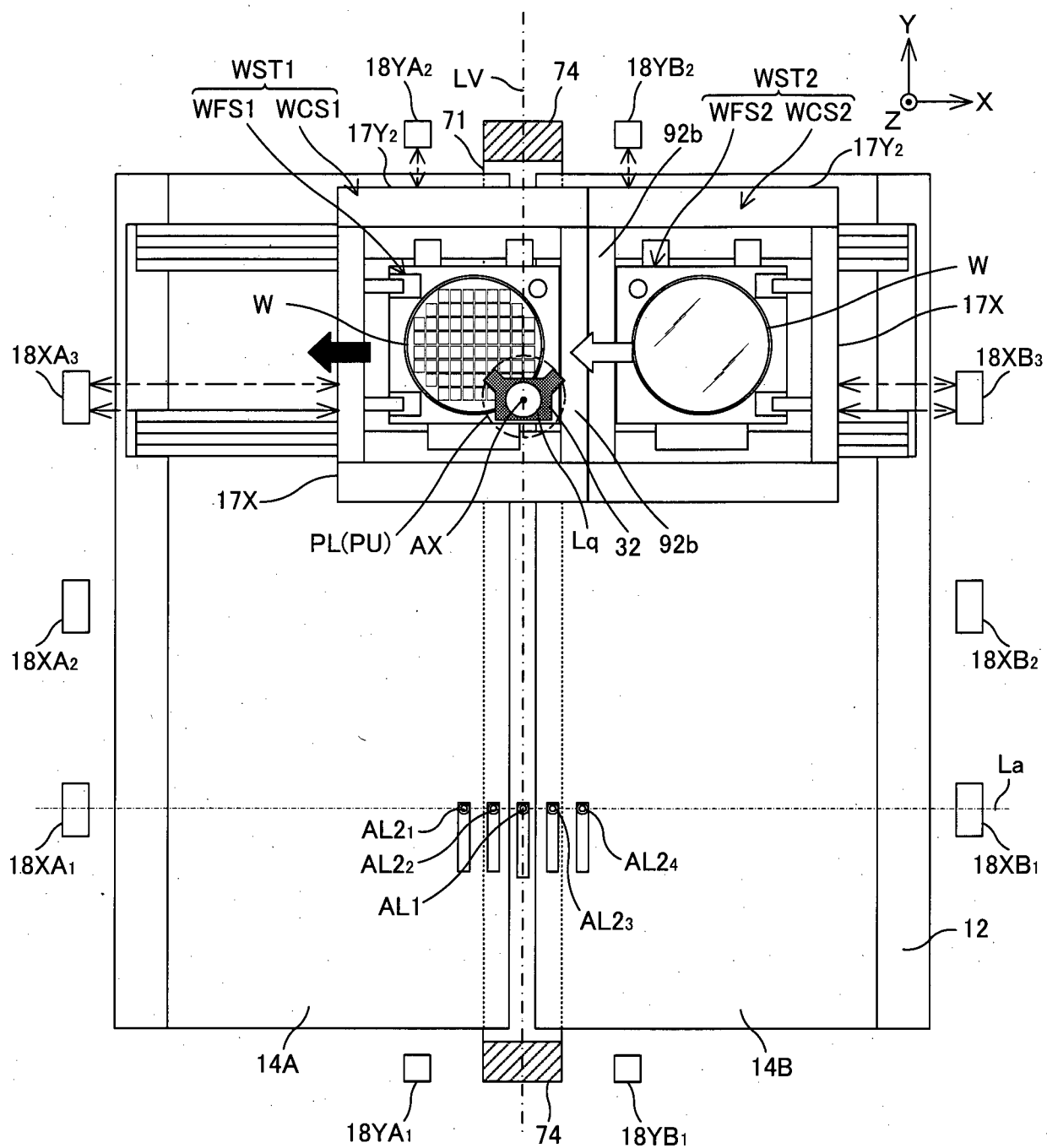
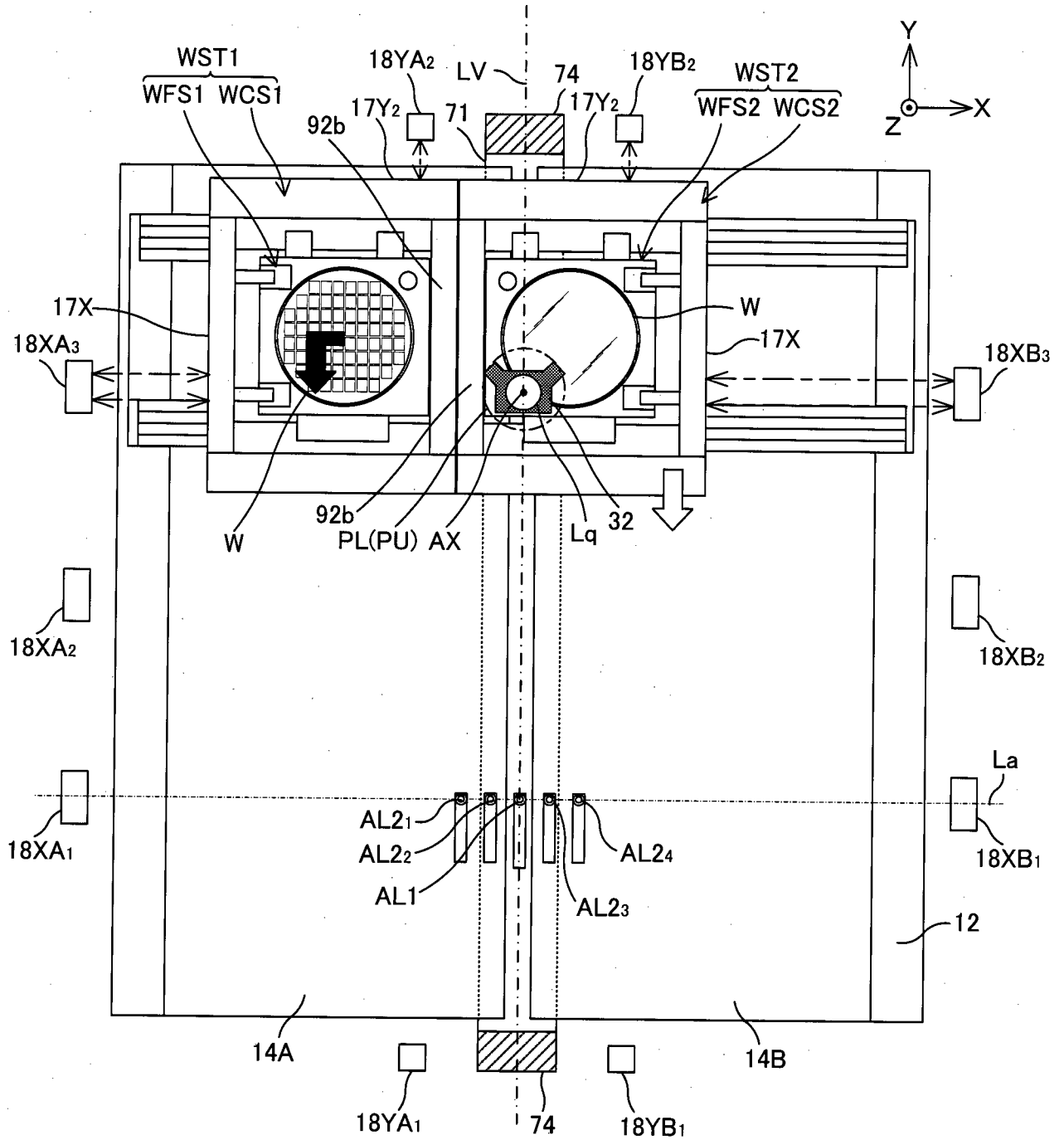


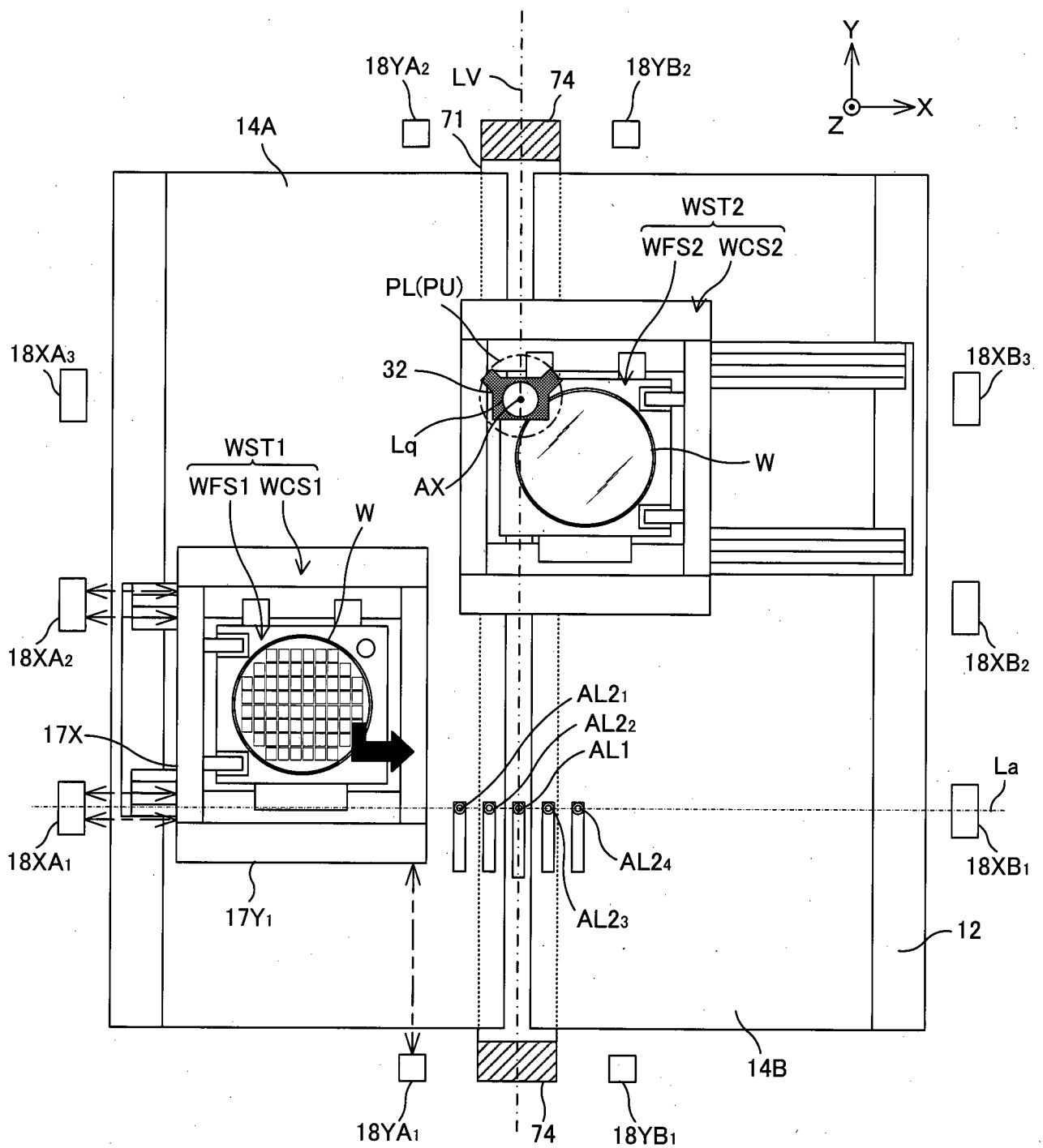
Fig. 11





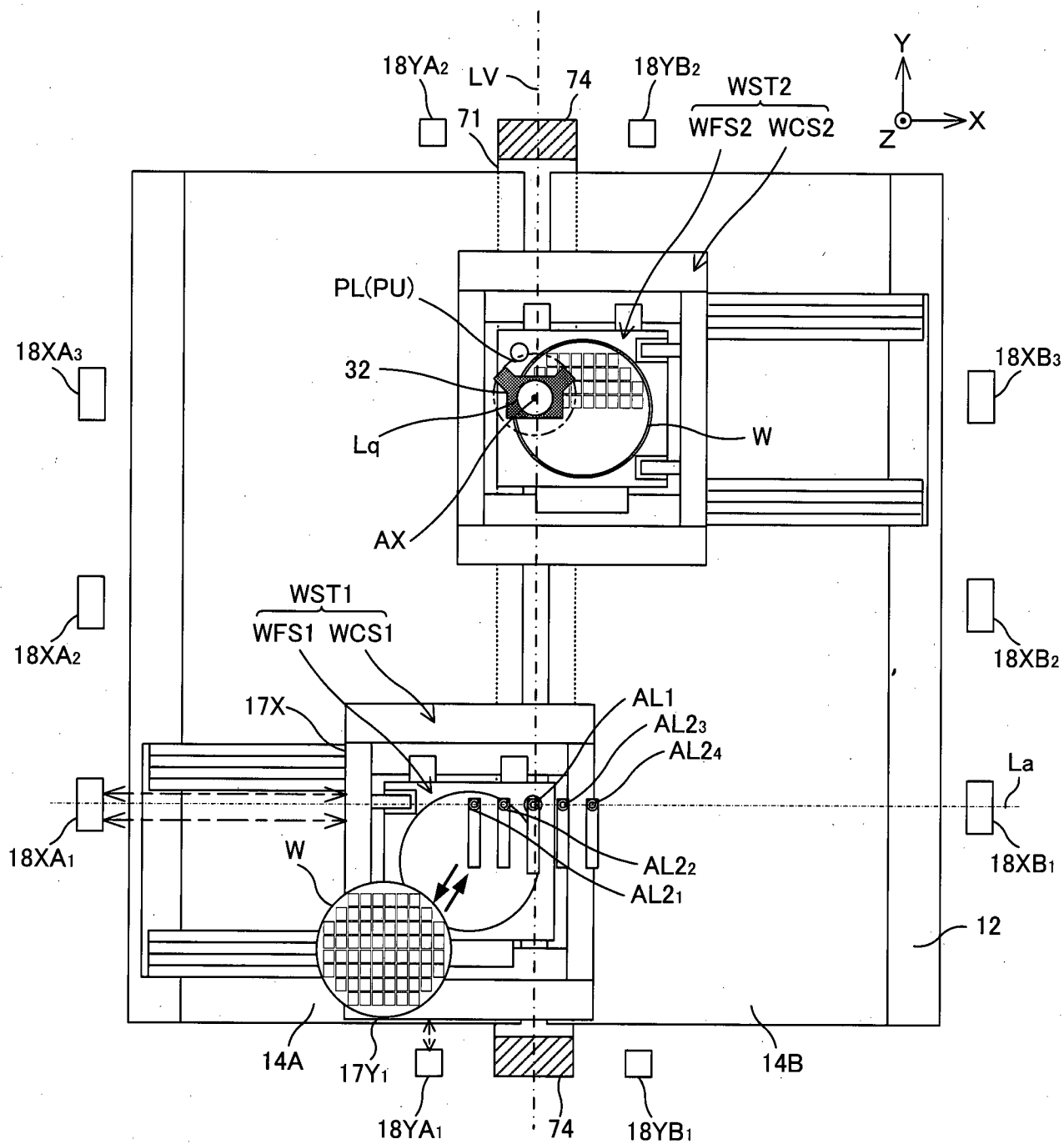
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Fig. 12



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*Fig. 13.*



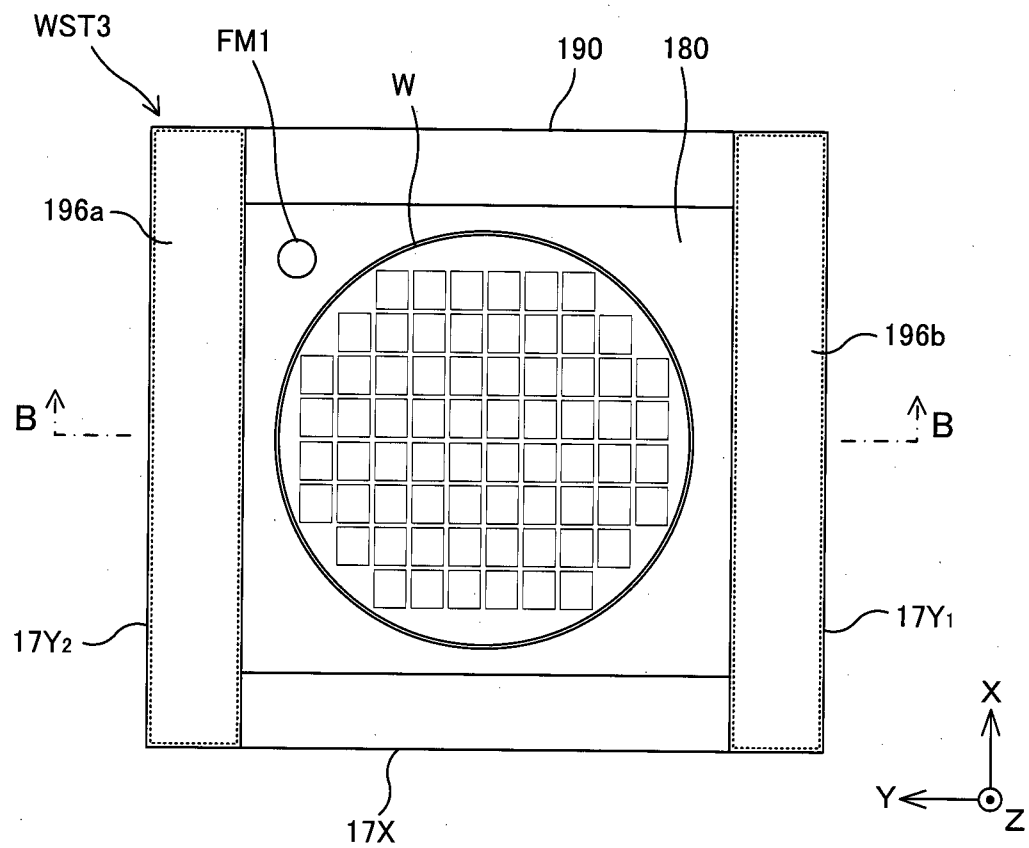




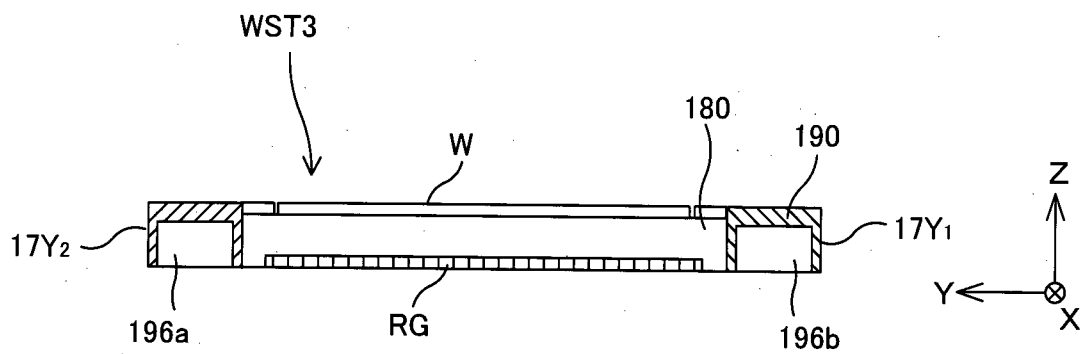
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Fig. 16

(A)



(B)



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Fig. 17

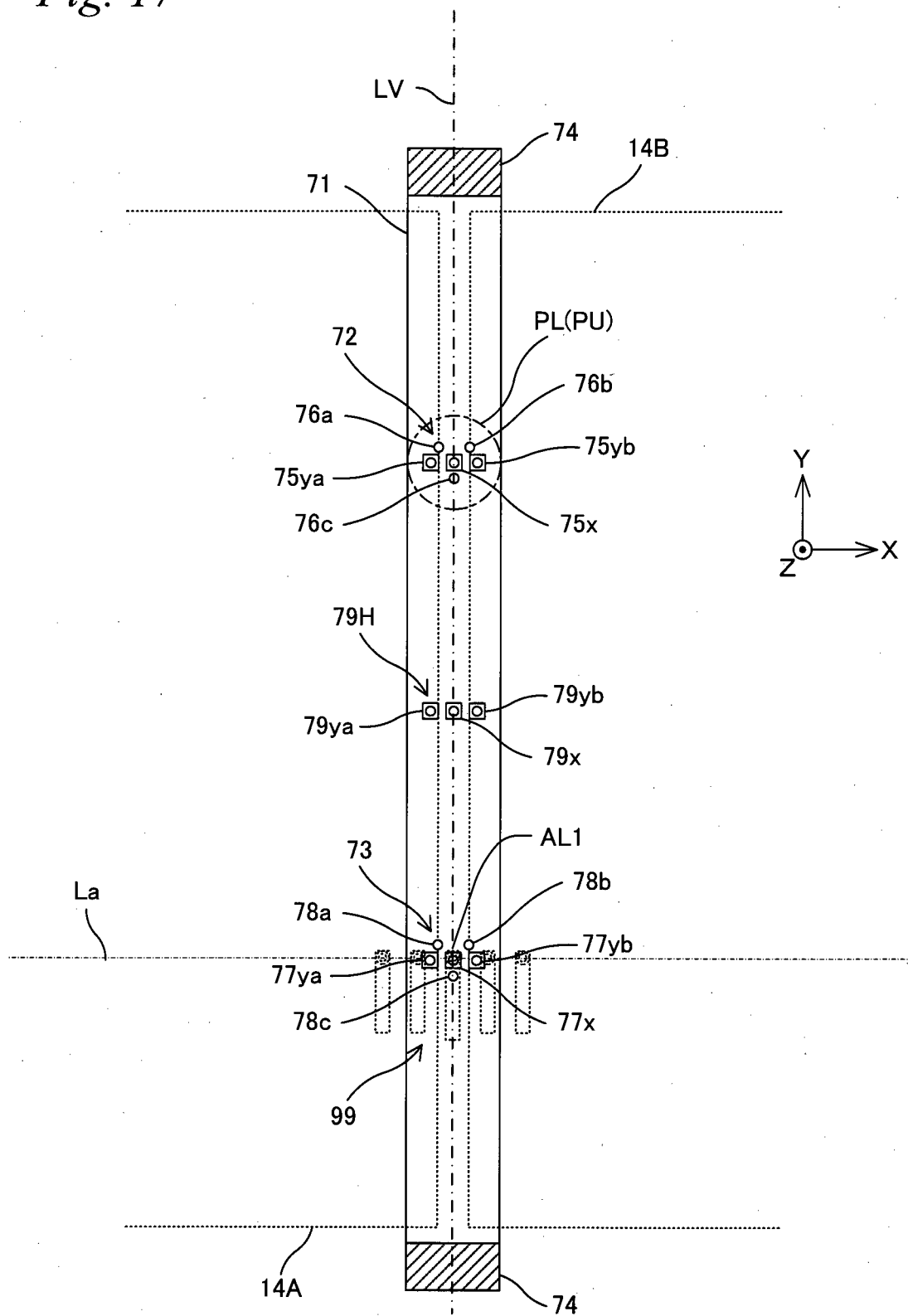
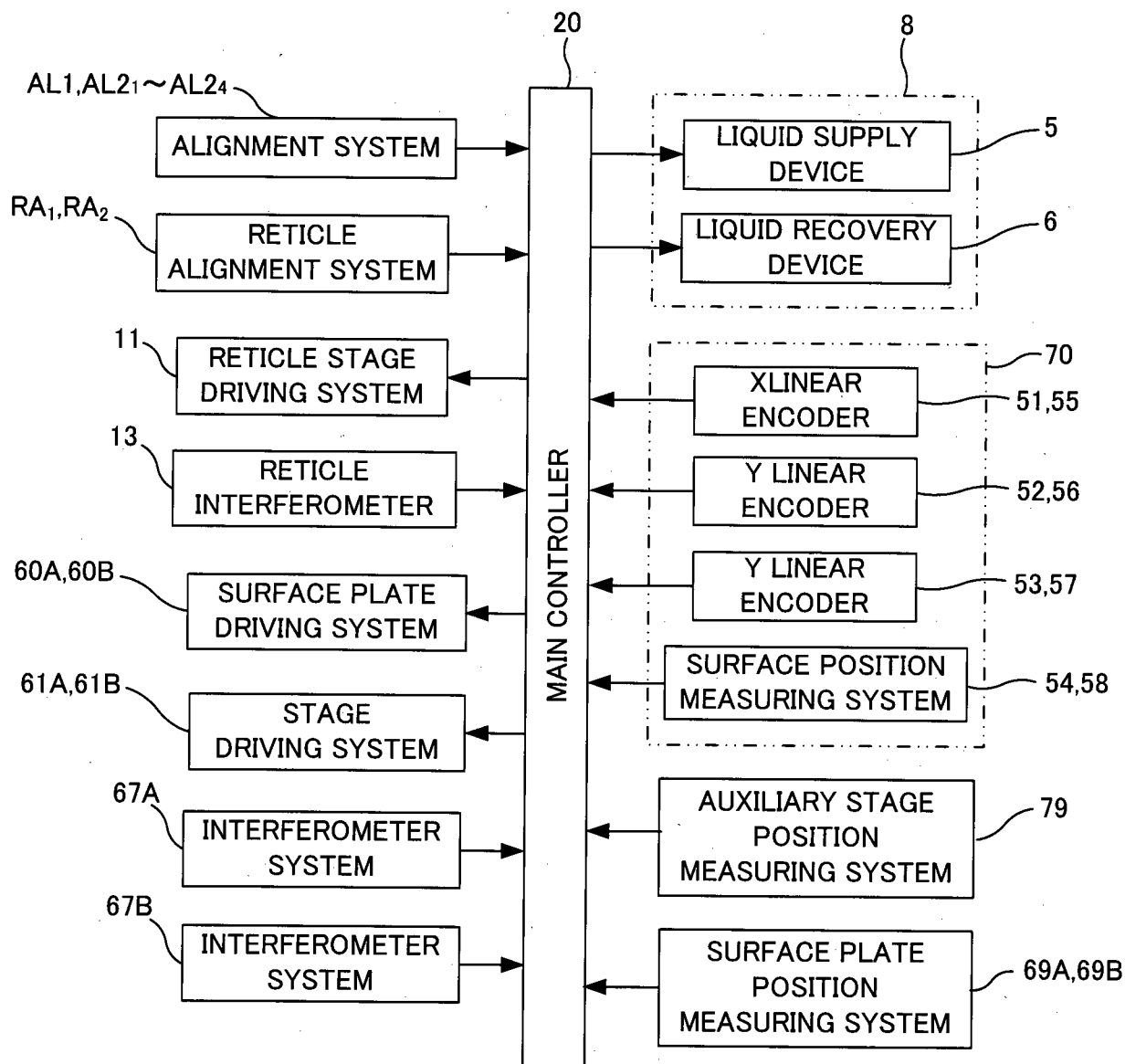


Fig. 18







*Fig. 20*

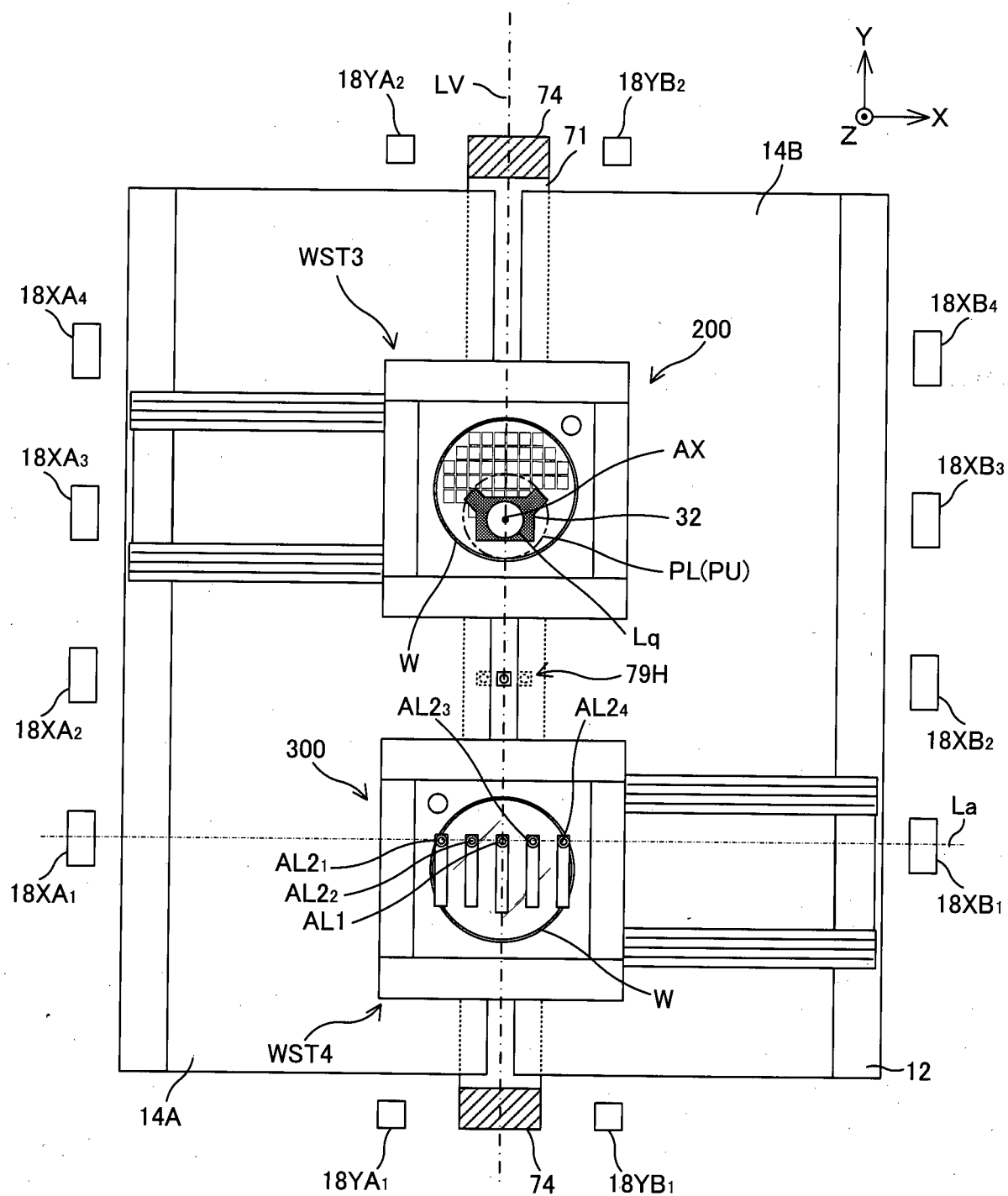




Fig. 22

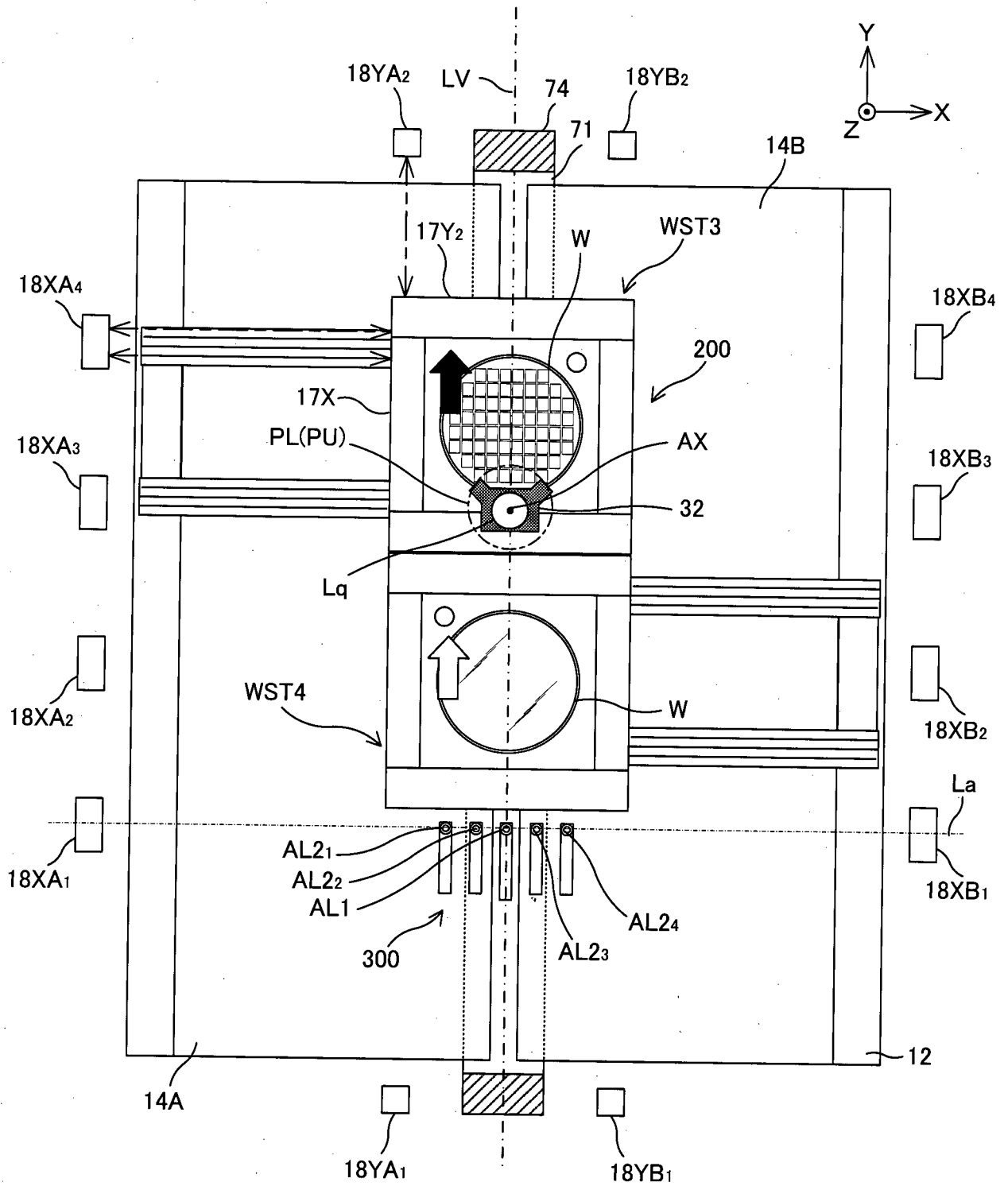
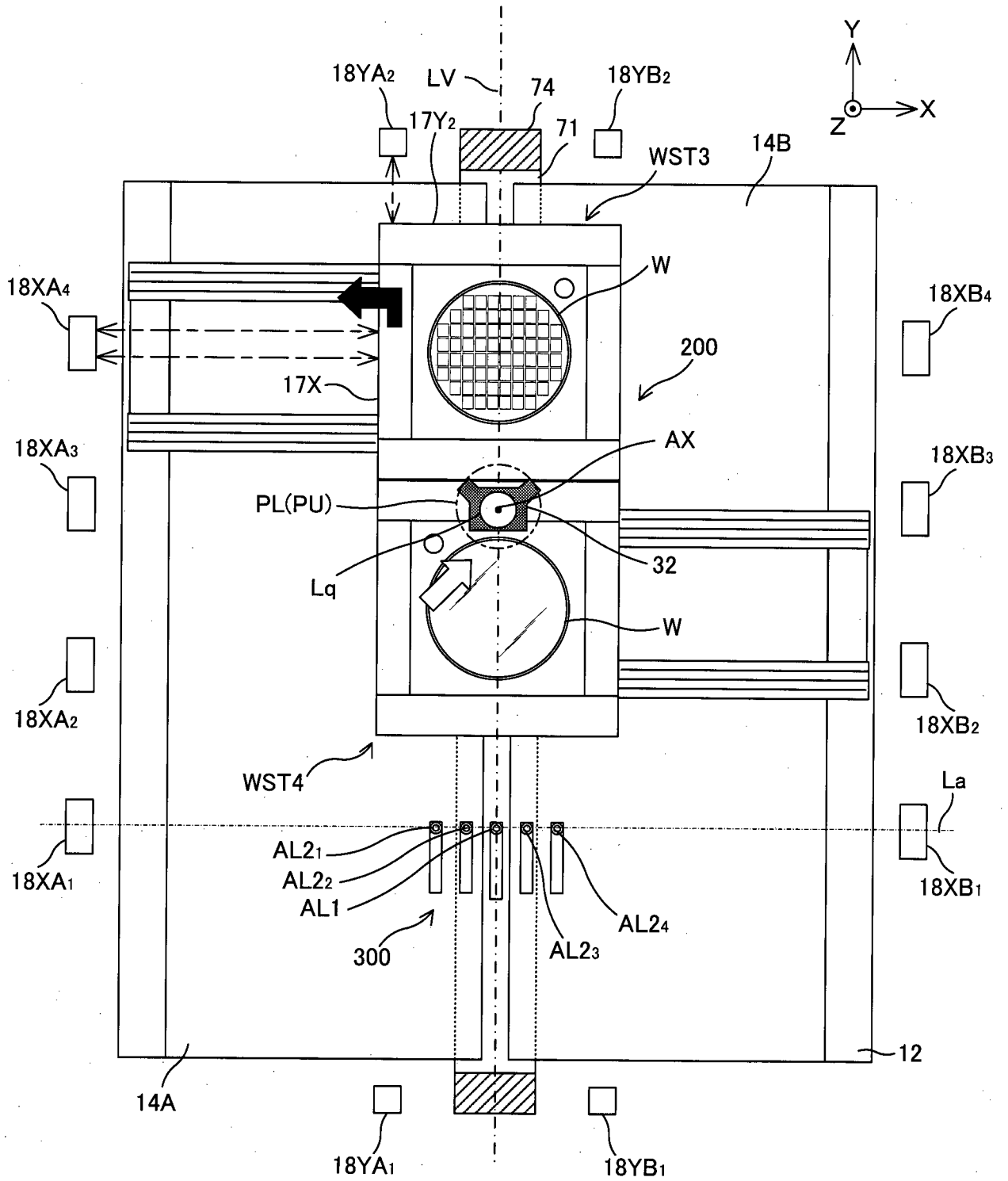
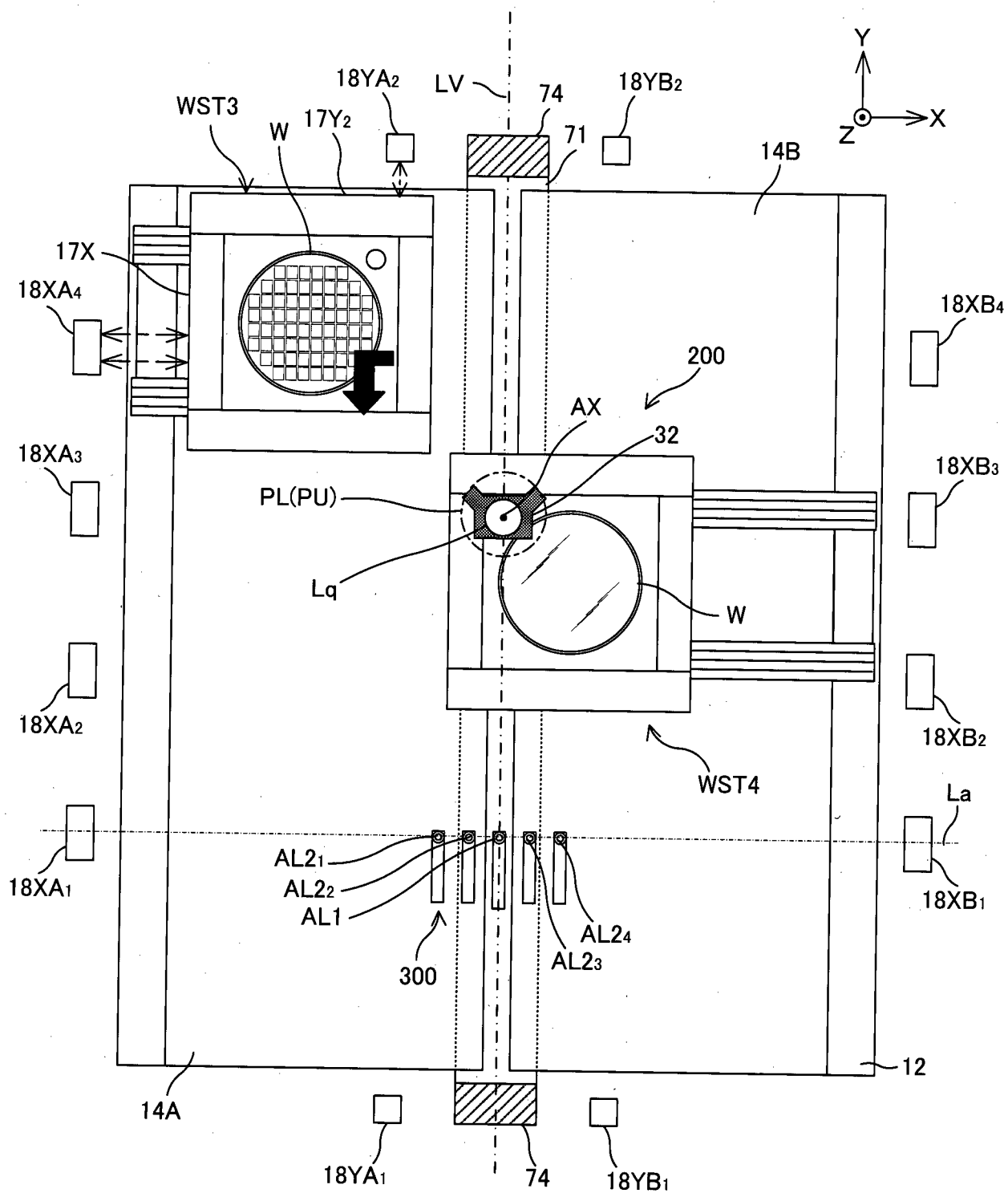


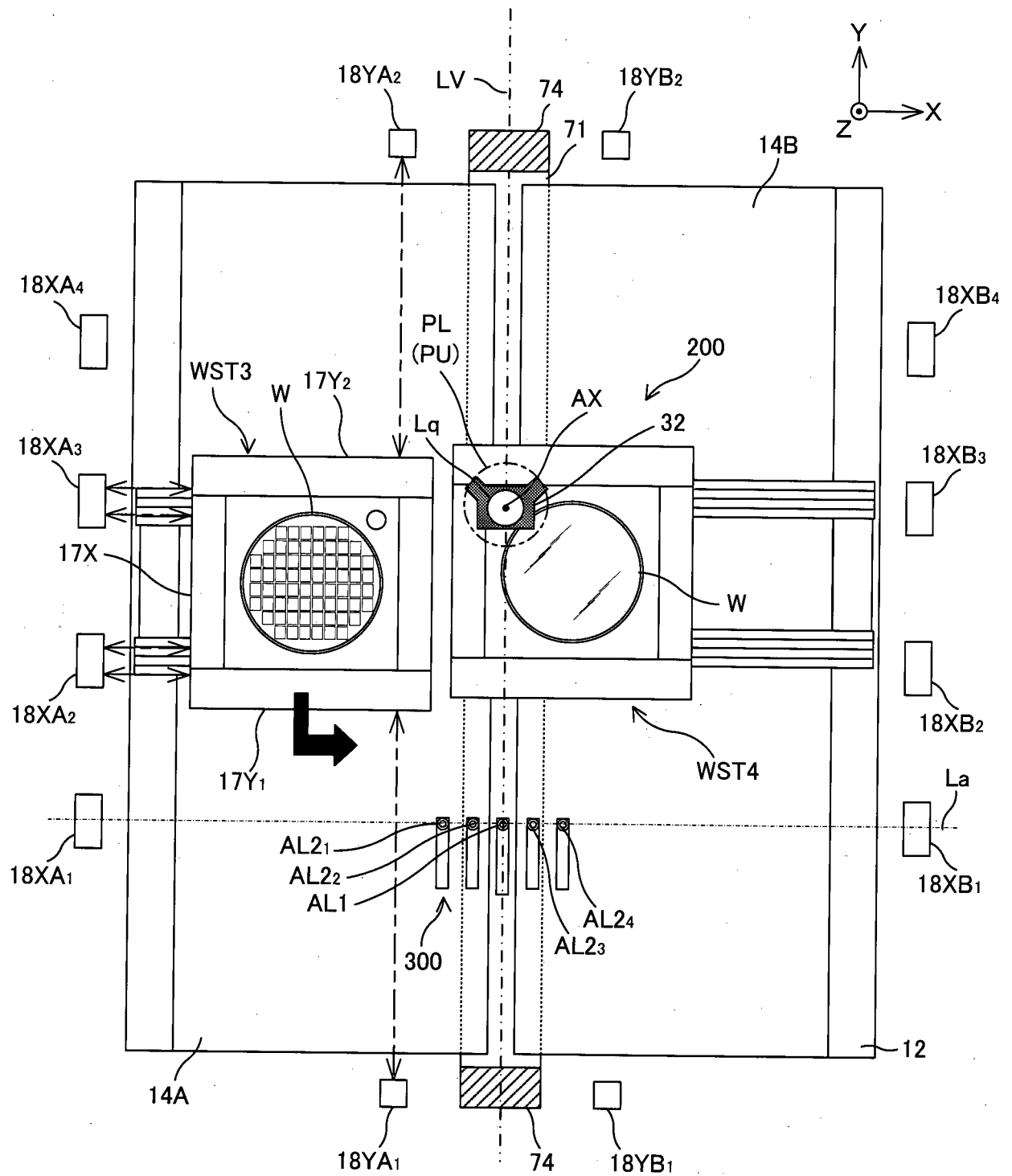
Fig. 23



*Fig. 24*

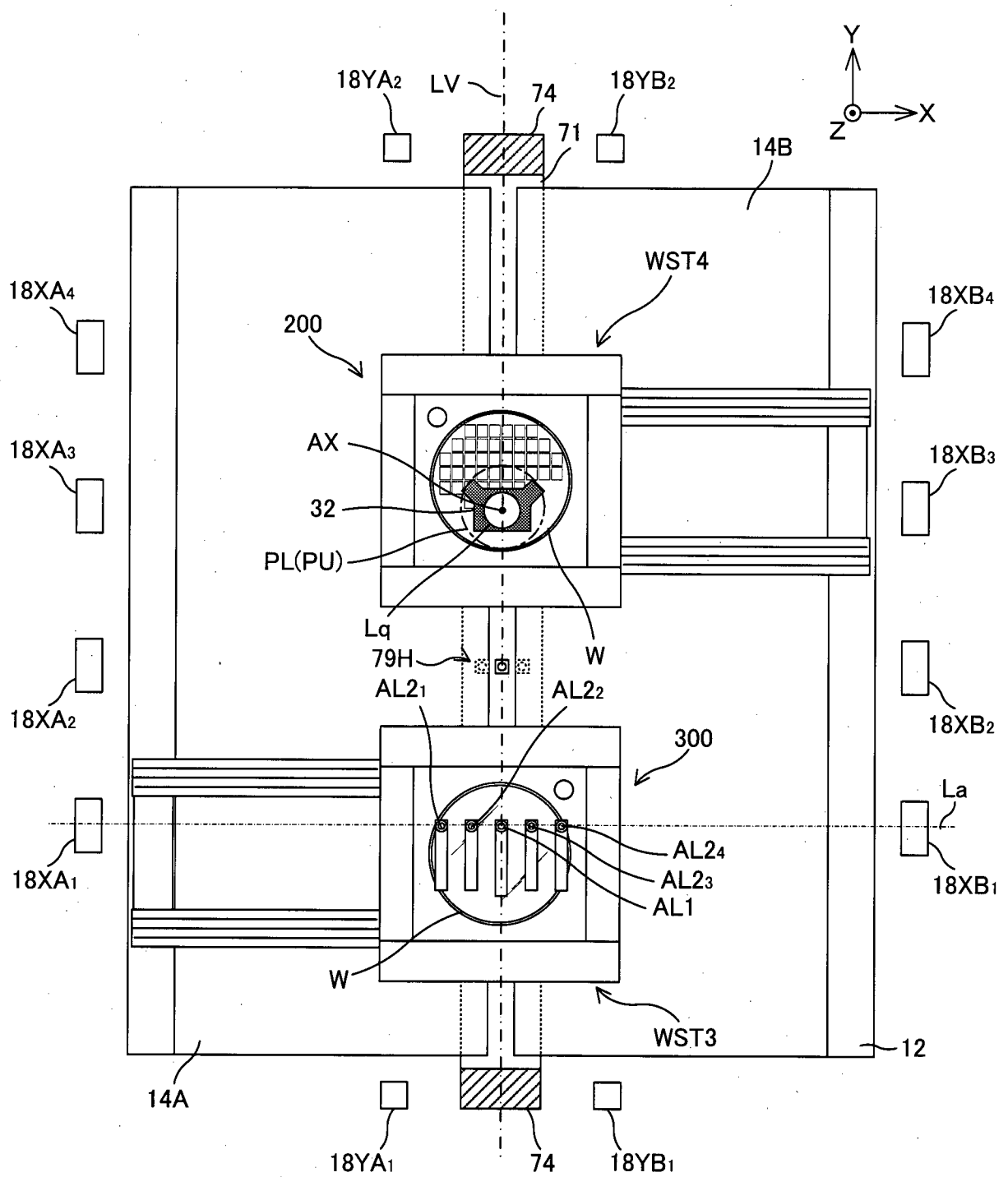


*Fig. 25*





*Fig. 27*





*Fig. 28*

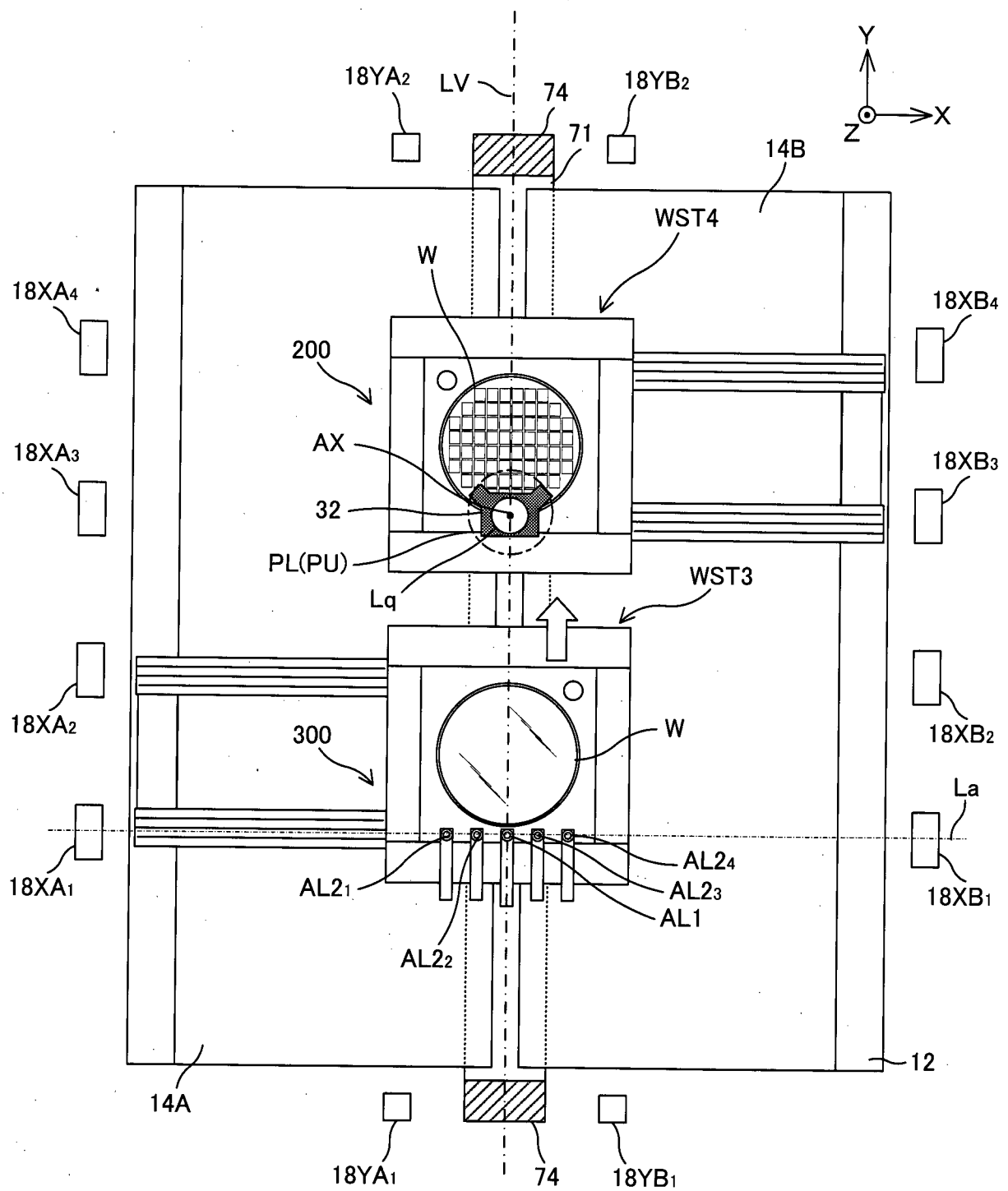
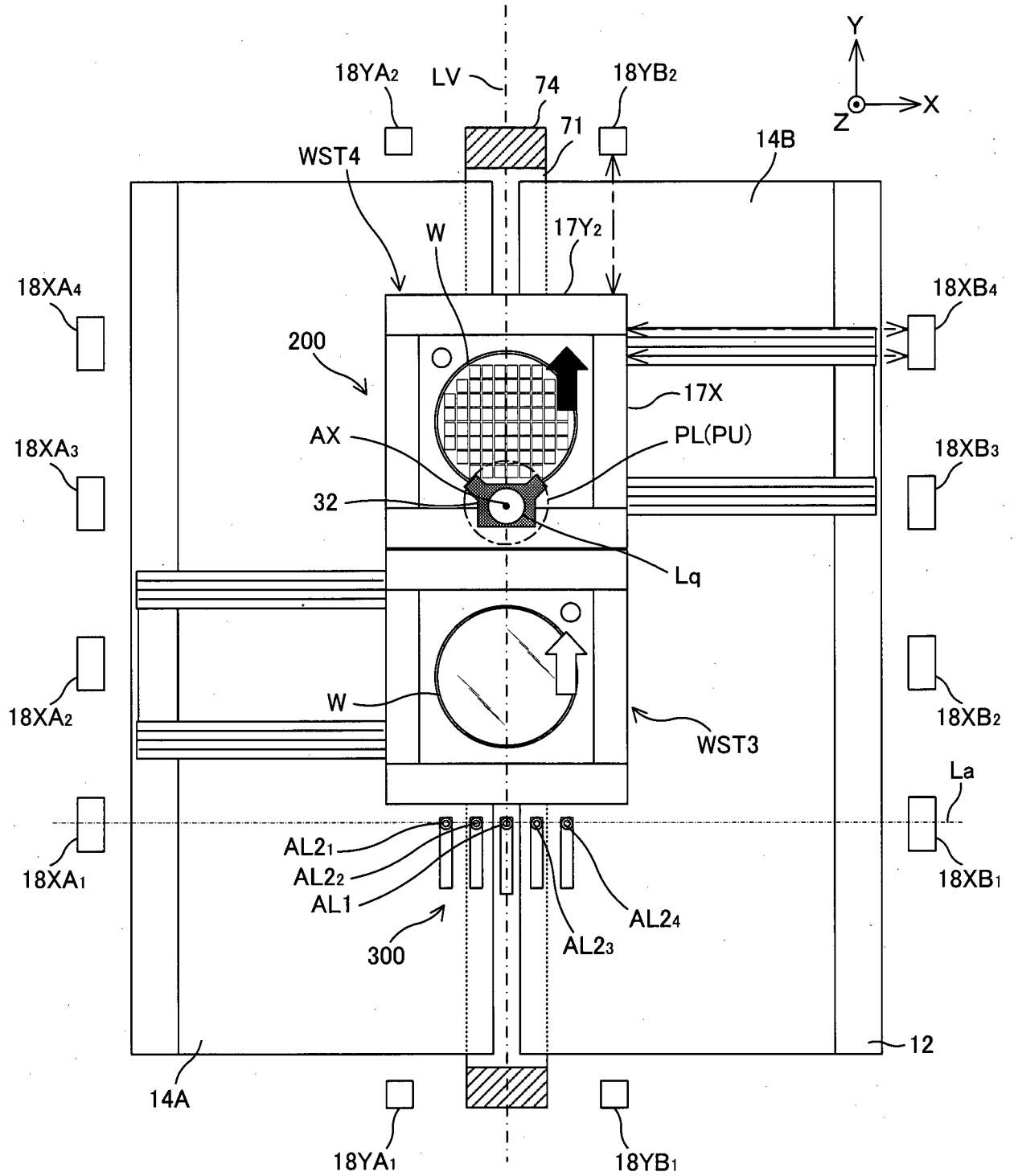
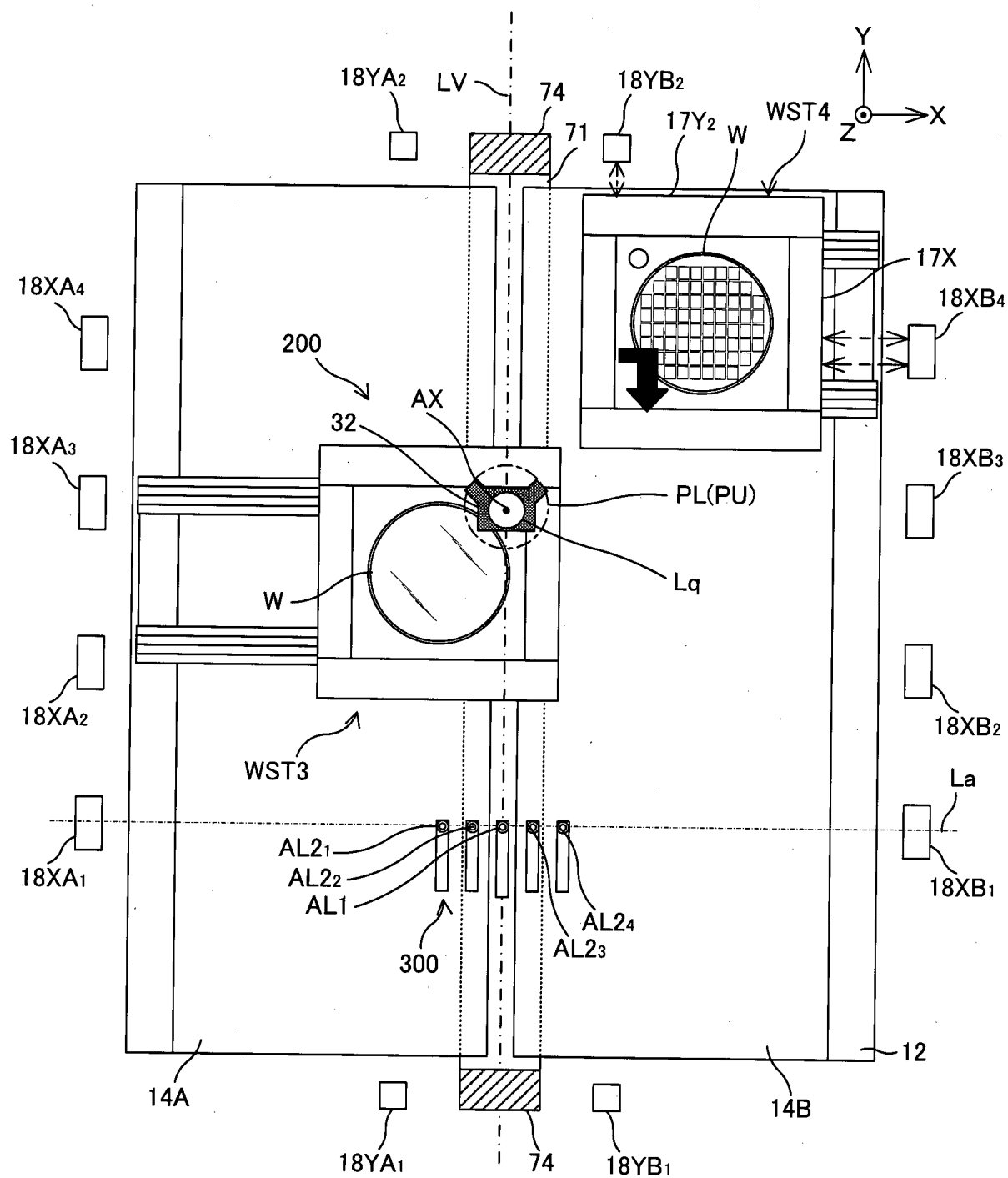


Fig. 29





*Fig. 31*



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Fig. 32

