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(54) Title: THREE DIMENSIONAL PIEZO ACTUATOR FOR PLANAR MOTION

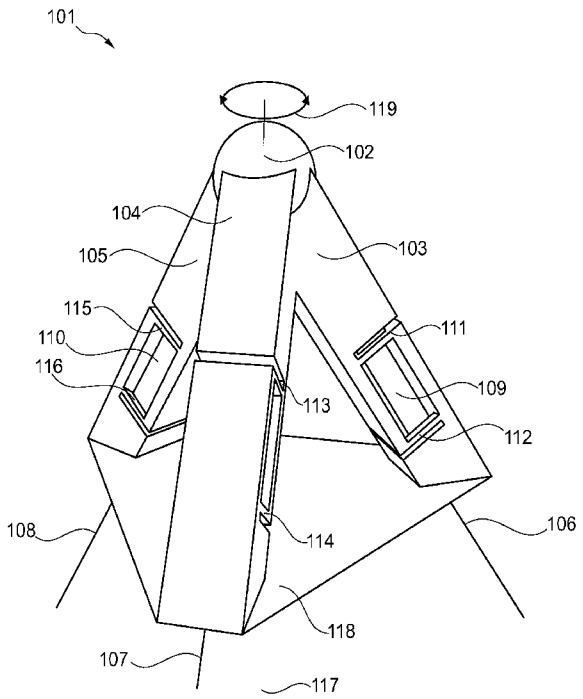


Fig. 1

(57) Abstract: An actuator system (101) comprising a tip (102), a first piezoelectric actuator (103) changing its length in a first direction in response to an applied voltage, a second piezoelectric actuator (103) changing its length in a second direction in response to an applied second voltage, a third piezoelectric actuator (104) changing its length in a third direction in response to an applied third voltage, wherein the first piezoelectric actuator, the second piezoelectric actuator and the third piezoelectric actuator are coupled with one of its respective ends to the tip (102), wherein the tip may follow three-dimensional trajectory in space (119) upon application of respective first, second and third voltages.

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Three dimensional piezo actuator for planar motion

FIELD OF THE INVENTION

The invention relates to an actuator system, a positioning module and a positioning system.

BACKGROUND OF THE INVENTION

Many applications require positioning and moving payloads supported by a stage. Historically, electromagnetic motors, linear guides, etc. have been used to drive and guide the stage. Recently, piezoelectric ultrasonic motors have gained attention for their low maintenance requirements, high speeds and precision.

Several types of piezoelectric ultrasonic motors are known from the article K. Spanner, Survey of the Various Operating Principles of Ultrasonic Piezomotors.

The known piezoelectric ultrasonic motors are adapted to drive a stage usually in only one translational or rotational direction. Typically, at least two modules each comprising a piezoelectric ultrasonic motor and a stage driven by said piezoelectric ultrasonic motor are cascaded to allow for positioning or movement of a payload in more than one degree of freedom. Managing the accuracy of the stage of the last of the cascaded modules is challenging since its position accuracy depends on the position accuracy of the stages of all preceding modules. Hence, modules having lower tolerances and accordingly being more expensive than the last module have to be used as base or intermediate modules.

WO 2007/058467 A1 discloses an omni-directional ultrasonic piezoelectric actuator system, which is capable of driving a mover in any arbitrary direction in a two-dimensional plane. The known actuator system comprises four piezoelectric actuators each changing its length in the same direction in response to an applied voltage. The four piezoelectric actuators are indirectly coupled to a common tip via two elongate beams. The tip may drive a plate supported by the actuator system in a gravity direction.

SUMMARY OF THE INVENTION

Hence, it may be an object of the present invention to provide an alternative actuator system and positioning module, positioning system for positioning and moving a payload.

Said object has been addressed with the actuator system, the positioning module and the positioning system according to the independent claims. Advantageous embodiments of the actuator system, the positioning module and the positioning system are described in the dependent claims.

An actuator system comprising a tip, a first piezoelectric actuator changing its length in a first direction in response to an applied first voltage, a second piezoelectric actuator changing its length in a second direction in response to an applied second voltage and a third piezoelectric actuator changing its length in a third direction in response to an applied third voltage, wherein the first piezoelectric actuator, the second piezoelectric and the third piezoelectric actuator are coupled in particular fixed, with one end to the tip. The tip may follow three-dimensional trajectory in space upon application of respective first, second and third voltages.

The actuator system may comprise only the first piezoelectric actuator, the second piezoelectric actuator, the third piezoelectric actuator and no further piezoelectric actuator.

The coupling of the first piezoelectric actuator, the second piezoelectric actuator and/or the third piezoelectric actuator to the tip may be a hinged support. Hence, the position of the end of the respective actuator with respect to the tip may not change and no torque may be transmitted from the respective actuator to the tip and vice versa. Such a coupling may reduce the risk of flexing and damaging the respective piezoelectric actuator and its elements.

A hinged support may be realized using ball-and-socket joints, wherein one ball-and-socket joint is nested within another ball-and-socket-joint. Alternatively, the hinged support may be realized using a gimbal, wherein each of the piezoelectric actuator is fixed to one of the frames of the gimbal. Finally, the hinged support may be realized using flexible or elastic hinges. The hinge support may be located directly at the piezoelectric element or anywhere on the strut along the main elongation axis of the piezoelectric element.

The first piezoelectric actuator, the second piezoelectric actuator and/or the third piezoelectric actuator may each be coupled to the tip such that a torque may be transmitted from the respective actuator to the tip. In other words, the coupling of the first

piezoelectric actuator, the second piezoelectric actuator and/or the third piezoelectric actuator to the tip may be a fixed support. Such a coupling may be established with less constructional effort.

The first piezoelectric actuator, the second piezoelectric actuator and the third piezoelectric actuator may be oriented to one another such that the first direction, the second direction and the third direction are orthogonal to one another. Said orientation may allow for an easier selection of the first, second and third voltage to obtain the desired elliptical movement of the tip, in particular the desired orientation of the ellipse in space.

According to a first embodiment of the actuator system, due to an orientation of the first piezoelectric actuator, the second piezoelectric actuator and the third piezoelectric actuator the first direction, the second direction and the third direction are linearly independent. Said embodiment may allow for an elliptical movement of the tip upon application of AC voltages to the first, second, and third piezoelectric actuator, wherein the ellipse may be oriented in any plane.

Linearly independent may in particular denote that no movement into the first, second or third direction may be expressed as a linear combination of movements in the other two directions.

According to a further embodiment of the actuator system the first piezoelectric actuator, the second piezoelectric actuator and the third piezoelectric actuator are directly coupled to the tip. No further element, in particular no beam or hinge, may be provided between the respective piezoelectric actuator and the tip. The direct coupling to the tip may allow for a more precise movement of the tip upon application of the respective first, second and third voltages. Hence, the position and speeds of a stage supported by the tip may be better controlled.

Moreover, according to an embodiment of the actuator system the tip has a spherical, pyramidal or conical shape. A pyramidal or conical shape may improve the adhesion of the tip with a stage supported by the tip in a direction perpendicular to the axis of gravity. The spherical form may be advantageous when the tip is intended for alternatively adhering and slipping with respect to a stage supported by the tip.

According to another embodiment of the actuator system at least one of the first piezoelectric actuator, the second piezoelectric actuator and the third piezoelectric actuator comprises a first piezoelectric element and a spring. The spring may allow for preloading the piezoelectric element. At least one of A, B and C means that one of A, B

and/or C may show the respective feature. For example, elements A, B may show the respective feature and C may not show the respective feature.

Moreover, according to an embodiment of the actuator system at least one of the first piezoelectric actuator, the second piezoelectric actuator and the third piezoelectric actuator may comprise a leaf spring. The predetermined force for preloading the piezoelectric element may be particularly easily be calculated for a leaf spring.

In a further embodiment of the actuator system at least one of the first piezoelectric actuator, the second piezoelectric actuator and the third piezoelectric actuator comprises two springs and the springs are arranged at opposite sides of the piezoelectric element with respect to the elongation direction of the piezoelectric element. Providing two springs at opposite sides of the piezoelectric element may lead to a more symmetrical elongation behavior of the respective piezoelectric actuator.

According to another embodiment of the actuator system at least one of the first piezoelectric actuator, the second piezoelectric actuator and the third piezoelectric actuator comprises a strut and slits are provided at opposing lateral sides of the strut to form the leaf spring. Providing the slits at opposing lateral sides of the strut may avoid that the strut becomes arch like but remains essentially straight upon elongation of the piezoelectric elements.

The strut may have a rectangular, in particular quadratic, cross section to make manufacturing of the actuator system easier. Each of the piezoelectric actuators may comprise a strut. Said struts and the tip may be formed as one piece together with the tip, for example by casting. Casting may allow dispensing with a manufacturing step for connecting the struts to the tip.

In a further embodiment of the actuator system the first piezoelectric actuator, the second piezoelectric actuator and the third piezoelectric actuators are similar, in particular identical. Providing similar, in particular identical, piezoelectric actuators may facilitate to the construction of the actuator system. Similar may in particular denote that the actuators deviate from one another only in view of manufacturing tolerances or tolerances with respect to the response of a piezoelectric element to an applied voltage.

Moreover, according to another embodiment of the actuator system, the first piezoelectric actuator, the second piezoelectric actuator and the third piezoelectric actuator are arranged rotationally symmetrically around an axis of symmetry through the tip. The rotational symmetry may allow for an easier construction of the actuator system.

Furthermore, the rotational symmetry may allow for an elliptical movement of the tip in any plane parallel to the axis of symmetry.

A positioning module comprising at least a first actuator system as described hereinbefore and a stage being supported by the tip of the first actuator system may allow for a more precise positioning and movement of a payload supported by the stage in more than one direction. The positioning module may have a reduced footprint and/or a smaller total volume compared to a positioning system according to the state of the art comprising two stacked positioning modules each having only one degree of freedom.

According to an embodiment the positioning module comprises a second actuator system as described hereinbefore and the stage is supported by the tips of the first and second actuator system. A positioning module comprising two actuator systems may allow for a more rapid movement of the stage.

An embodiment of the positioning module may also comprise a third actuator system to allow for a positioning of the stage in a third direction.

Providing the positioning module with more than three actuator systems as described hereinbefore may be advantageous for supporting heavier payloads on the stage and/or increase the stiffness of the drive train allowing higher position accuracy.

Further in an embodiment of the positioning module a contact surface of the stage being supported by the tips of the actuator systems is planar. A planar surface of the stage may allow for an easy movement and/or positioning in a translational direction.

Moreover, according to another embodiment of the positioning module a contact surface of the stage being supported by the tips of the actuators is part of the surface of a sphere. Said spherical contact surface may allow for tilting the stage in an arbitrary direction.

A positioning system comprising a positioning module as described hereinbefore, a power module adapted to provide first, second and third voltages to the respective first, second and third actuator of the first and second actuator system for moving the stage in a translational direction or tilting the stage may allow for an easy transportation or positioning of a payload.

In an embodiment of the positioning system at least one voltage provided by the power module corresponds to a resonance frequency of an piezoelectric element of the respective actuator. Operating a piezoelectric element at the resonance frequency may allow for higher movement or tilting speeds.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawing

Fig. 1 shows an actuator system according to an exemplary embodiment;

Fig. 2 is a perspective view of a detail of an actuator system according to an exemplary embodiment in;

Fig. 3 is a first cross-sectional view of the detail;

Fig. 4 is a second cross-sectional view of the detail;

Fig. 5 is a third cross-sectional view of the detail;

Fig. 6 shows a positioning module according to an exemplary embodiment;

Fig. 7 shows a positioning module according to an exemplary embodiment;

Fig. 8 shows an actuator system according to an exemplary embodiment;

Fig. 9 shows an actuator system according to an exemplary embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

The actuator system 101 depicted in Figure 1 comprises a first piezoelectric actuator 103, a second piezoelectric actuator 104 and a third piezoelectric actuator 105. The first piezoelectric actuator 103, the second piezoelectric actuator 104 and the third piezoelectric actuator 105 are configured as tetrahedron struts. Each of the piezoelectric actuators 103, 104, 105 comprises a piezoelectric element 109, 110 (the piezoelectric element of the second piezoelectric actuator 104 is hidden) and two leaf springs 111 and 112, 113 and 114 as well as 115 and 116, respectively. The leaf springs 111 to 116 may serve for pre-tensioning the three piezoelectric elements 109, 110. Moreover, the leaf springs 111 to 116 may serve as guides for said three piezoelectric elements 109, 110 as will be described below.

The first piezoelectric actuator 103, the second piezoelectric actuator 104 and the third piezoelectric actuator 105 are coupled with their respective upper end to the tip 102. As shown in the embodiment of Figure 1, the tip 102 may have the shape of a sphere. The spherical form of the tip 102 may be particularly suitable if the tip 102 shall alternatively adhere to and slip with respect to a stage supported by the tip. In another embodiment the tip 102 may also have a pyramidal or conical shape. Such a form may improve the adhesion of the tip 102 to the stage, when the tip 102 does not slip with respect to the stage but is completely lifted off in the none-driving part of the tip movement.

First, second and third voltages may be applied to the first piezoelectric actuator 103, the second piezoelectric actuator 104 and the third piezoelectric actuator 104 or

more precisely to the piezoelectric elements 109, 110 thereof. Due to the piezoelectric effect the three piezoelectric elements 109, 110 will change their respective length in response to the applied voltage. Accordingly, the first piezoelectric actuator 103 will change its length in a first direction 106, the second piezoelectric actuator 104 will change its length in a second direction 107 and the third piezoelectric actuator 105 will change its length in a third direction 108.

In view of the orientation of the first piezoelectric actuator 103, the second piezoelectric actuator 104 and the third piezoelectric actuator 105, the first direction 106, the second direction 107 and the third direction 108 are linearly independently. Thus, a movement in one of said directions, e.g. in the first direction 106, may not be expressed as a linear combination of movements in the other two directions, e.g. in the second direction 107 and the third direction 108.

The ends of the first piezoelectric actuator 103, the second piezoelectric actuator 104 and the third piezoelectric actuator 105 not coupled to the tip 102 may be connected to a ground plate 118 or simply stand on the ground. Connecting respective ends of the first piezoelectric actuator 103, the second piezoelectric actuator 104 and the third piezoelectric actuator 105 to a common ground plate 118 may lead to every change in length of one of the first piezoelectric actuator 103, the second piezoelectric actuator 104 and the third piezoelectric actuator 105 to translate in a corresponding movement of the tip. Any movement of the bottom ends of the first piezoelectric actuator 103, the second piezoelectric actuator 104 and the third piezoelectric actuator 105 may be prevented.

The first, second and third piezoelectric actuator 103, 104, 105 may also be chamfered and stand directly on the ground. Providing three smaller ground contact surface may avoid any rocking of the actuator system 101 with respect to the ground. A lateral movement of the bottom ends of the first, second and third piezoelectric actuator 103, 104, 105 may be avoided due to the friction between the respective end and the ground. For this purpose friction enhancing materials, e.g. rubber pads, may be provided at the bottom ends of the first, second and third piezoelectric actuator 103, 104, 105.

The first, second and/or third voltage may be an AC voltage having a frequency of 10 kHz to 1 MHz. The frequency of the first, second and/or third voltage may in particular lead to an excitation of a resonant mode of the respective piezoelectric element driven by said voltage. The frequency of the first, second and/or third voltage may be selected to be identical to the resonance frequency of the respective piezoelectric element. Operating the piezoelectric element 109, 110 at the resonance frequency may allow for

higher movement speeds. The first, second and third voltage may have the same frequency or different frequency. Moreover, the first, second and third voltage may have different or the same amplitudes and different or the same phases.

Using the same AC or DC voltage for the first, second and third voltage leads to an up and down movement of the tip. The application of the same DC voltage may allow for a precise positioning of a stage supported by the tip 102 in the direction of the axis 117. The same AC voltage may be used if only a vibration of a stage supported by the tip and not movement of the stage is intended. Moreover, AC voltages may be applied to the first, second and third piezoelectric actuators 103, 104, 105 such that the tips follows an elliptical trajectory 119 in a plane parallel to the axis 117.

As the first direction 106, second direction 107 and third direction 108 are linear independently, it is possible to select the first, second and third voltage in such a way that the trajectory of the tip 102 will be elliptical, wherein the plane of the ellipse is parallel to the axis of symmetry 117.´

Figure 2 shows a part of a strut 203 of a piezoelectric actuator in greater detail. A piezoelectric element 201 is nested in the strut 203. Two slits 202, 206 are provided at opposite lateral sides of the strut 203. The slits 202, 206 are used to provide leaf springs 204, 205. Figure 3 shows a cross-section, wherein a strut 301, a slit 303 and the nested piezoelectric element 302 are more clearly visible. In the cross-section of figure 4 the strut 401, the leaf spring 403 and the nested piezoelectric element 402 may be recognized. In figure 5 the windows 503 in the strut 501 to the piezoelectric element 502 are shown, which windows 503 may also be seen in figure 2. The leaf springs 403 guide the piezoelectric element 402, 502 such that it cannot move through the window 503 when vibrating. On the other hand the piezoelectric element 402, 502 is free to move in a direction perpendicular to the leaf springs 403.

Figure 6 shows a positioning module 601. The positioning module 601 comprises a stage 605, which is supported by the tips 606, 607, 608 of a first, second and third actuator system 602, 603, 604. The contact surface of the stage 605 being in contact with the tips 606, 607, 608 is planar. Depending on the movements of the tips 606, 607, 608 the stage 605 and a payload placed thereon may be moved or positioned in any direction in the plane of the contact surface 605 or rotated.

For example, the first, second and third actuator system 602, 603, 604 may be driven such that the movement of the respective tips 606, 607, 608 may resemble that of the

continuous ellipses 610. Due to these periodic movements of the tips 606, 607, 608 the stage 605 will move in a direction 611, i.e. to the left.

Alternatively, voltages may be applied to the first, second and third actuator system 602, 603, 604 such that that tips follow a trajectory according to the dotted ellipses 612. Accordingly, the stage will rotate around the axis 613 in a clockwise direction 614.

Figure 7 shows a further positioning module 701 comprising a first actuator system 702, a second actuator system 703, a third actuator system 704 and a stage 705. The contact surface 706 of the stage 705 being supported by the tips 708, 709, 710 of the first, second and third actuator system 702, 703, 704 is spherical. Hence, a payload being supported at the upper side 707 of the stage may be rotated around the axis of gravity and tilted in any direction depending on voltages applied to the first, second and third actuator system 702, 703, 704.

Figure 8 shows a further embodiment of an actuator system 801comprising a first piezoelectric actuator 802, a second piezoelectric actuator 803 and a third piezoelectric actuator 804. The first piezoelectric actuator 802, the second piezoelectric actuator 803 and the third piezoelectric actuator 804 are coupled with the upper one of their respective ends to a tip 805. Each of the piezoelectric actuators 802, 803, 804 comprises a piezoelectric element 806, 807 (the piezoelectric element of the third piezoelectric actuator 804 is hidden) and two leaf springs 808, 809 and 810, 811, respectively.

Moreover, each of the piezoelectric actuators 802, 803, 804 comprises two hinges 812 and 813, 814 and 815 as well as 816. The hinges 812 to 816 may be an elastic hinge. The hinges 812 to 816 may reduce the risk of flexing in one direction and damaging the respective piezoelectric actuator and its elements. The springs 808 to 811 may also be adapted to serve as hinges and may reduce the risk of flexing in the other direction.

The actuator system 901 depicted in Figure 9 includes a first piezoelectric actuator 902, a second piezoelectric actuator 903 and a third piezoelectric actuator 904. The upper ends of the first, second and third piezoelectric actuator 902, 903, 904 are coupled to a common tip 905. Each of the piezoelectric actuators 902, 903, 904 comprises a piezoelectric element 906, 907 and two leaf springs 908 and 909, 910 and 911.

Furthermore hinges 912 to 915 and 916 to 919 may be provided to avoid bending of the respective piezoelectric actuator 902, 903, 904 in two-directions.

A positioning module may comprise only a single type of actuator systems, for example a type according to the embodiments of figure 1, 8 or 9, or it may comprise different types of actuator system. For example, a positioning system may comprise one actuator

system according to figure 1, one actuator system according to figure 8 and one actuator system according to figure 9.

A positioning module according to one of the described embodiments may in particular be used in a low pressure environment also called vacuum environment. Due to the positioning module not requiring any lubrication a very low pressure may be maintained in said environment.

Moreover, a positioning module according to one of the described embodiments may be used in a low temperature environment. Reliable movement or tilting of a pay load may be assured, because no lubrication, which may solidify at low temperatures, in particular at the temperature of liquid nitrogen or liquid helium, is necessary for driving the stage.

A positioning module according to one of the described embodiments may very suitable for use in environments having stringent requirements on electromagnetic interference and magnetic flux disturbances. Typical examples for such environments are e-beam lithography systems, electron microscopes and ion beam machining equipment. In particular, a positioning module according to one of the described embodiments may lead to a magnetic stray field below 1 μT.

Hence, a positioning module according to one of the described embodiments may in particular be useful in semiconductor manufacturing.

CLAIMS:

1. Actuator system (101) comprising

a tip (102);

a first piezoelectric actuator (103) changing its length in a first direction (106) in response to an applied first voltage;

a second piezoelectric actuator (104) changing its length in a second direction (107) in response to an applied second voltage;

a third piezoelectric actuator (105) changing its length in a third direction (108) in response to an applied third voltage;

wherein the first piezoelectric actuator (103), the second piezoelectric actuator (104) and the third piezoelectric actuator (105) are coupled with one of its respective ends to the tip (102).

2. Actuator system (101) according to claim 1,

wherein, due to an orientation of the first piezoelectric actuator (103), the second piezoelectric actuator (104) and the third piezoelectric actuator (105) the first direction (106), the second direction (107) and the third direction (108) are linearly independent.

3. Actuator system (101) according to any one of claims 1 or 2,

wherein the first piezoelectric actuator (103), the second piezoelectric actuator (104) and the third piezoelectric actuator (105) are directly coupled to the tip (102).

4. Actuator system (101) according to any one of claims 1 to 3,

wherein the tip (102) has a spherical, pyramidal or conical shape.

5. Actuator system (101) according to any one of claims 1 to 4,

wherein at least one of the first piezoelectric actuator (103), the second piezoelectric actuator (104) and the third piezoelectric actuator (105) comprises

a piezoelectric element (109, 110)
and a spring (111, 112, 113, 114, 115, 116).

6. Actuator system (101) according to claim 5,
wherein the spring is a leaf spring (111, 112, 113, 114, 115, 116).

7. Actuator system (101) according to any one of claims 5 or 6,
wherein at least one of the first piezoelectric actuator (103), the second piezoelectric actuator (104) and the third piezoelectric actuator (105) comprises two springs (111 and 112, 113 and 114, 115 and 116); and
wherein the springs (111 and 112, 113 and 114, 115 and 116) are arranged at opposite sides of the piezoelectric element (109, 110) along the first direction, the second direction and/or the third direction (106, 107, 108), respectively.

8. Actuator system (101) according to claim 6 or 7,
wherein at least one of the first piezoelectric actuator (103), the second piezoelectric actuator (104) and the third piezoelectric actuator (103) comprises a strut, and
wherein slits are provided at opposing lateral sides of the strut to form the leaf spring (111, 112, 113, 114, 115, 116).

9. Actuator system (101) according to any one of claims 1 to 8,
wherein the first piezoelectric actuator (103), the second piezoelectric actuator (104) and the third piezoelectric actuator (105) are configured as tetrahedron struts.

10. Actuator system according to any one of claims 1 to 9,
wherein the first piezoelectric actuator (103), the second piezoelectric actuator (104) and the third piezoelectric actuator (105) are arranged rotationally symmetrical around an axis of symmetry (117) through the tip (102).

11. Positioning module (601) comprising,
at least a first actuator system (602, 603, 604) according to any one of the claims 1 to 10,
a stage (605) being supported by the tip (606, 607, 608) of the first actuator system (602, 603, 604).

12. Positioning module (601) according to claim 11 comprising

a second actuator system (602, 603, 604) according to any one of the claims 1 to 4,

wherein the stage (605) is supported by the tips (606, 607, 608) of the first and second actuator system (602, 603, 604).

13. Positioning module (601, 701) according to any one of claims 11 or 12,

wherein a contact surface (609, 706) of the stage (605, 705) being supported by the tips (606, 607, 608, 708, 709, 710) of the actuator systems (602, 603, 604, 702, 703, 704) is planar or is part of the surface of a sphere.

14. Positioning system comprising

a positioning module (601, 701) according to any one of claims 11 to 13,

a power module,

wherein the power module is adapted to provide first, second and third voltages to the respective first, second and third actuator of the first and second actuator system (602, 603, 604, 702, 703, 704) for moving the stage (605) in a translational direction or rotating the stage (605, 705) or tilting the stage (705).

15. Positioning system according to claim 14,

wherein at least one voltage corresponds to a resonance frequency of a piezoelectric element of the respective actuator.

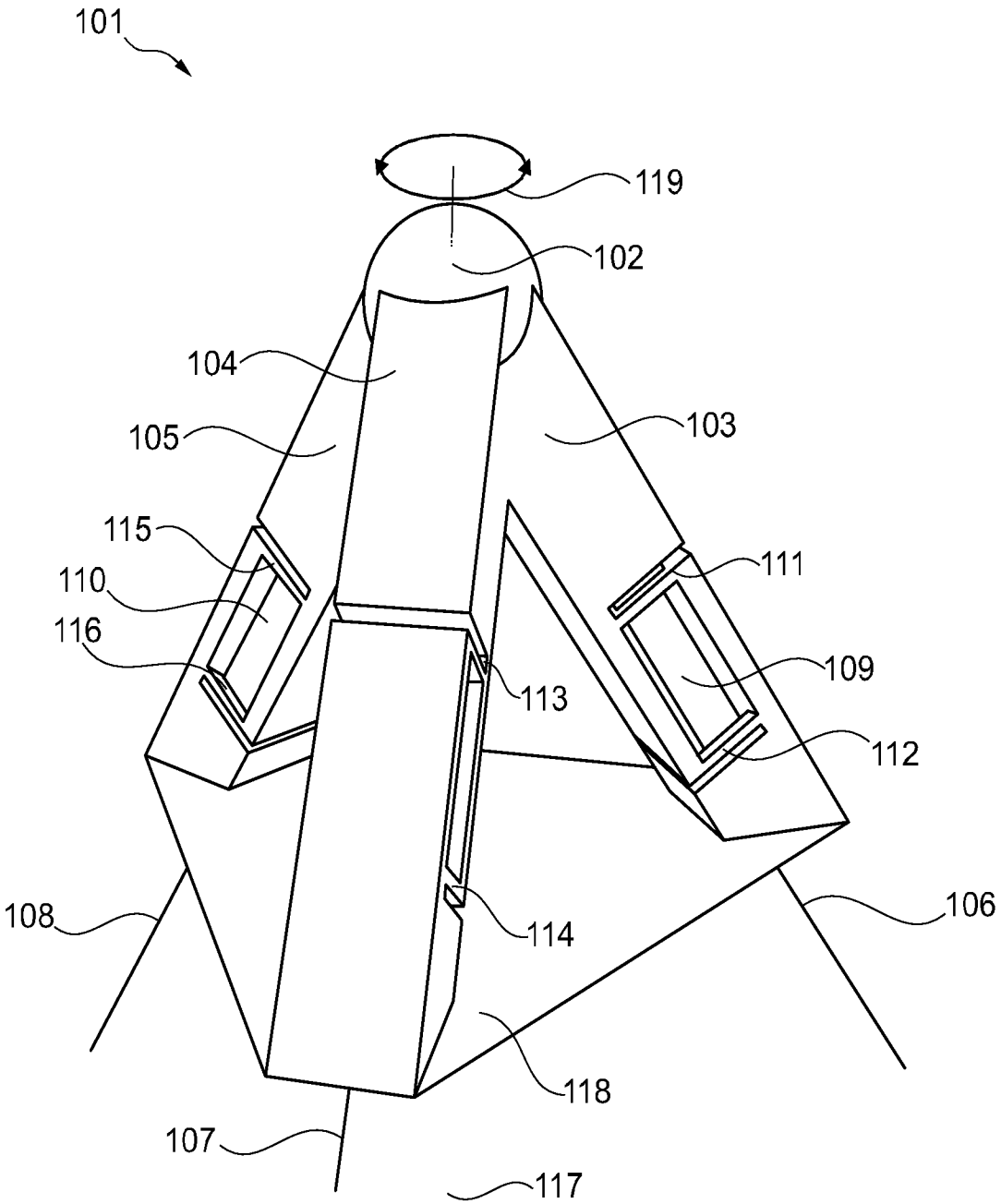

101
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Fig. 1

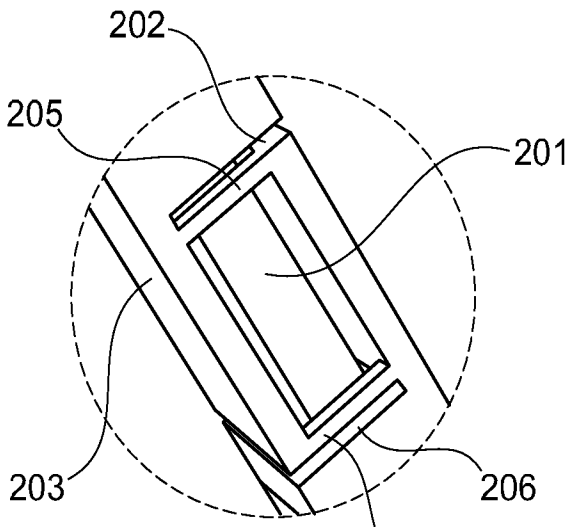


Fig. 2

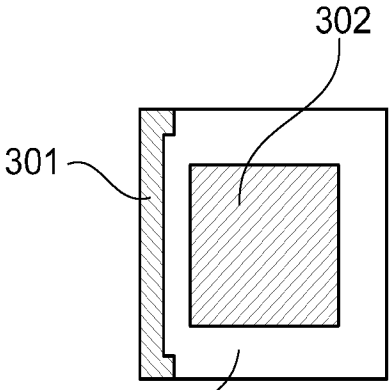


Fig. 3

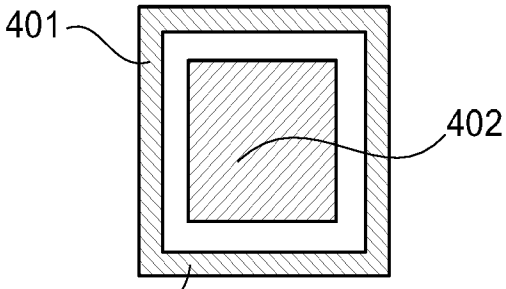


Fig. 4

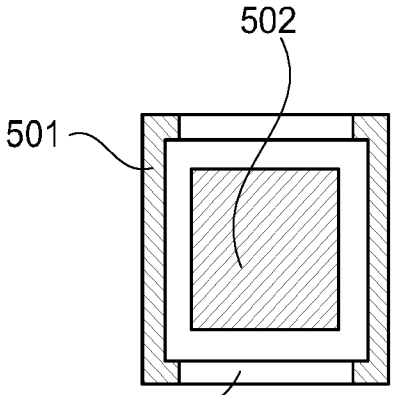


Fig. 5

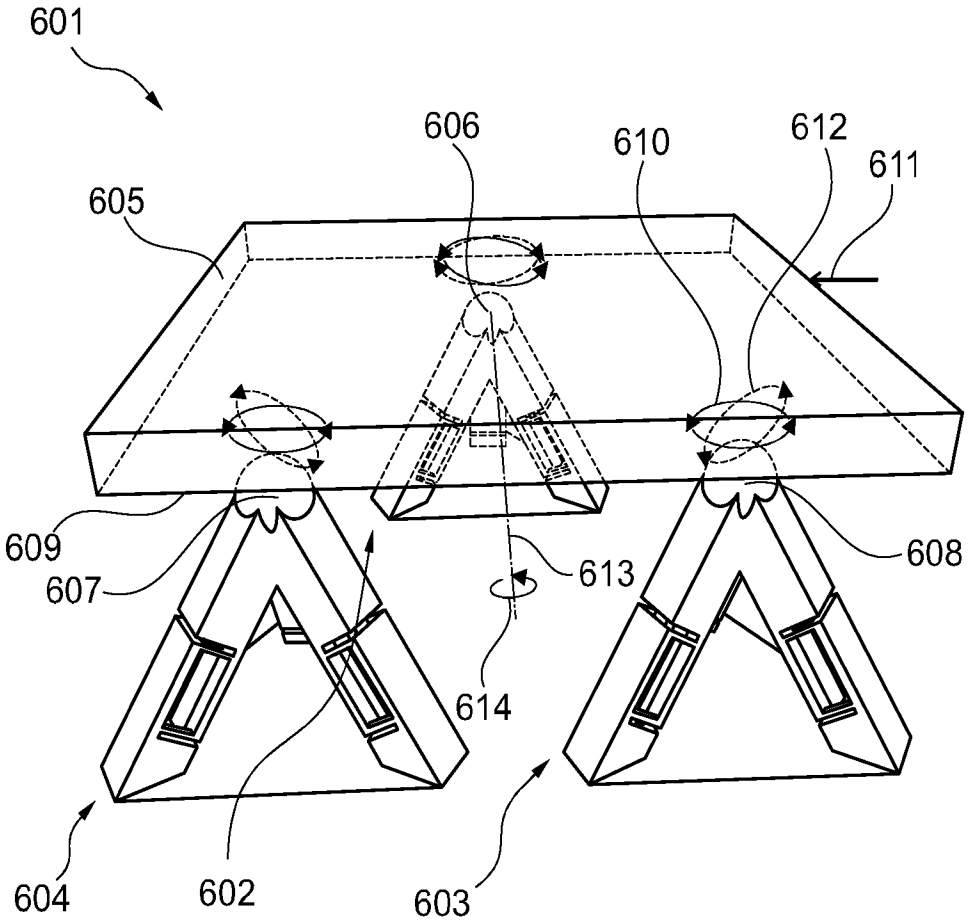


Fig. 6

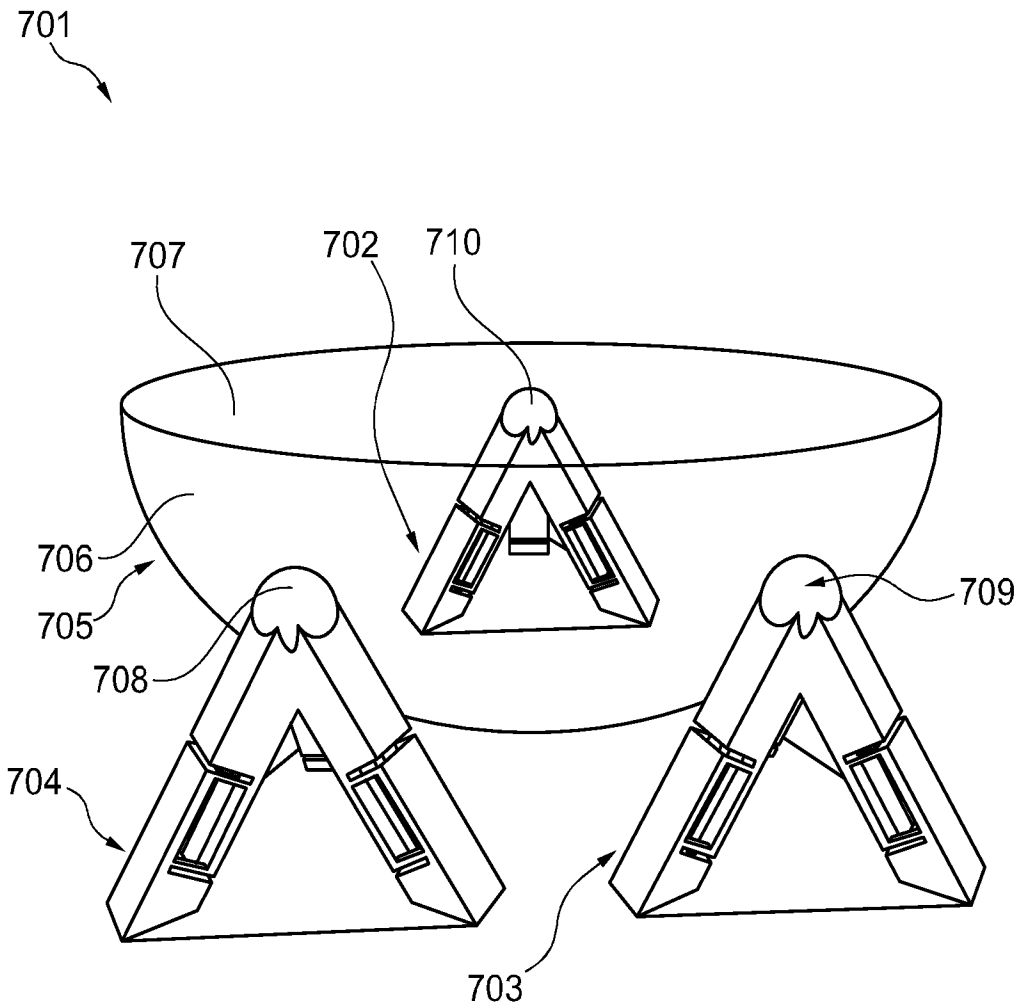


Fig. 7

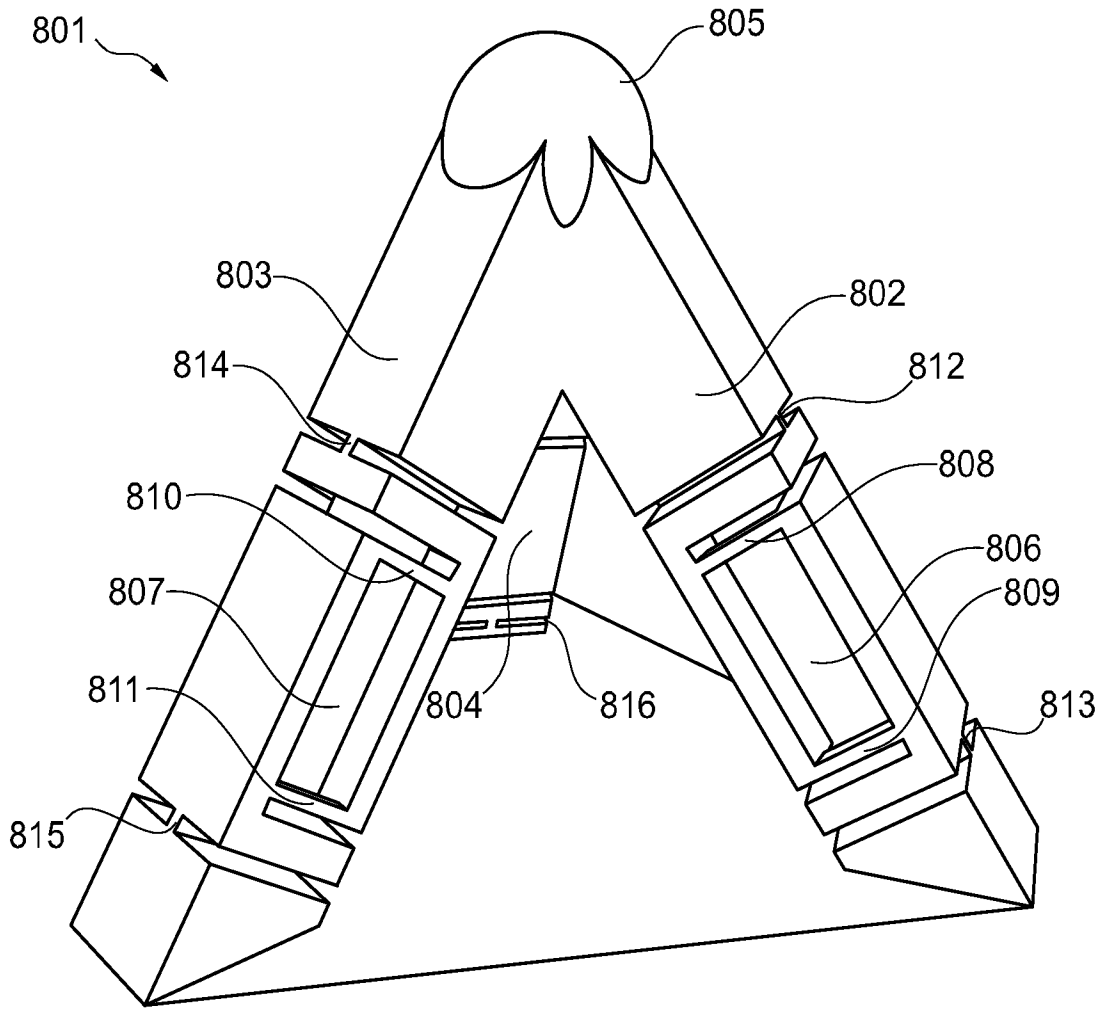


Fig. 8

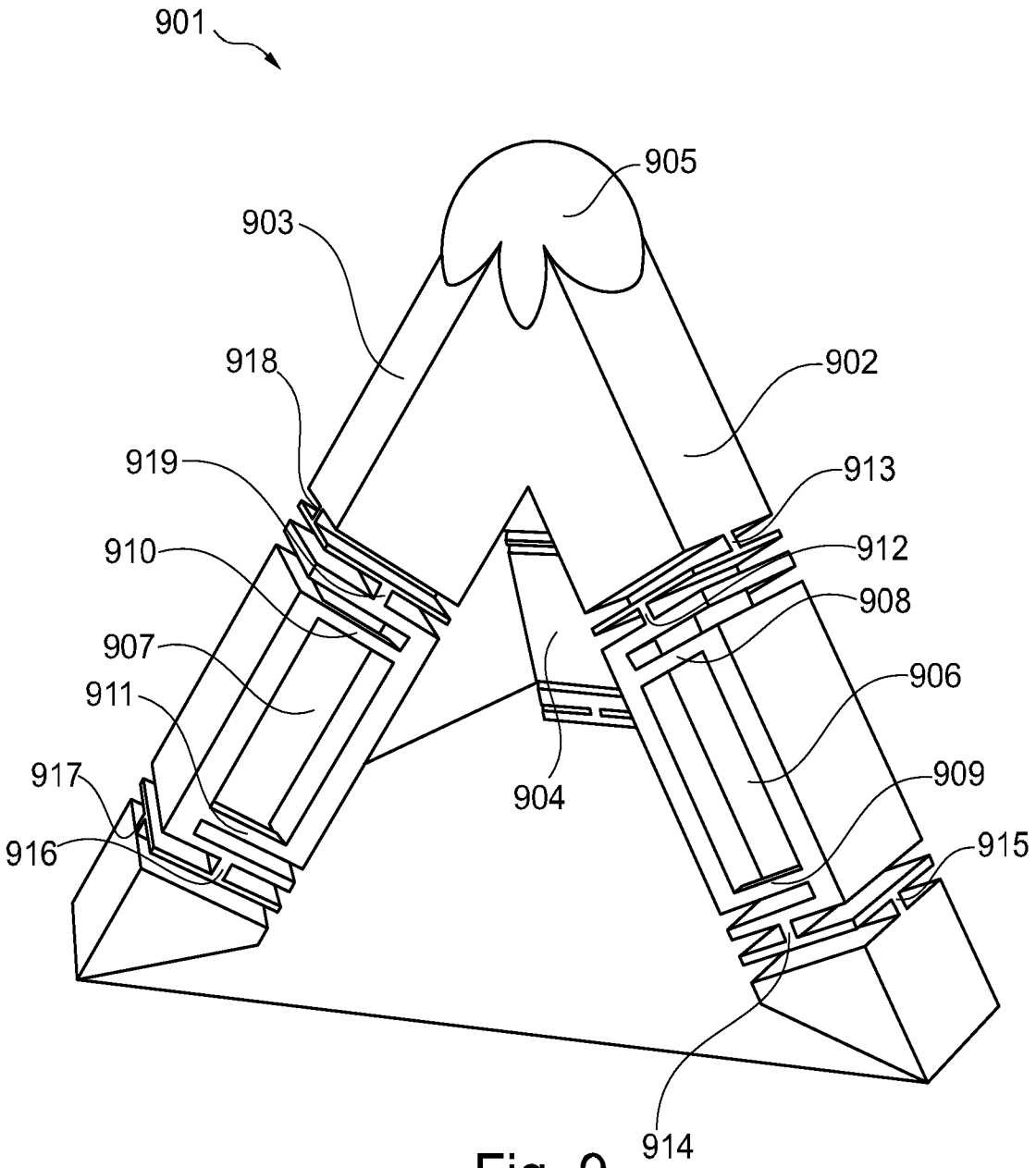

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Fig. 9

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/072188

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02N2/00 H02N2/02
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02N

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP H03 159581 A (RICOH KK) 9 July 1991 (1991-07-09)	1-4,9,10
Y	abstract	15

X	JP S63 161883 A (MARCON ELECTRONICS CO) 5 July 1988 (1988-07-05)	1-5,9-14
Y	abstract figures 1-3	6-8,15

X	JP H03 35104 A (FUJI ELECTROCHEMICAL CO LTD) 15 February 1991 (1991-02-15)	1-5,9,10
Y	abstract	15

Y	US 2001/020809 A1 (MATSUO TAKASHI [JP] ET AL) 13 September 2001 (2001-09-13) paragraph [0055]; figure 27	15

	-/--	

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
19 November 2015	01/12/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Steiner, Markus

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/072188

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US 5 189 578 A (MORI KENJI [JP] ET AL) 23 February 1993 (1993-02-23) column 2, lines 20-29 column 5, lines 40-53 figures 2,20 -----	6-8

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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