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(71) Applicant: CAMBRIDGE MECHATRONICS LIMITED [GB/GB]; St John's Innovation Centre, Cowley Road, Cambridge Cambridgeshire CB4 0WS (GB).

(72) Inventors: EDDINGTON, Robin; c/o Cambridge Mechatronics Limited, St John's Innovation Centre, Cowley Road, Cambridge Cambridgeshire CB4 0WS (GB). HAWORTH, James; c/o Cambridge Mechatronics Limited, St John's Innovation Centre, Cowley Road, Cambridge Cambridgeshire CB4 0WS (GB).

(74) Agent: MAIN, James Edward; 14 South Square, Gray's Inn, London Greater London WC1R 5JJ (GB).

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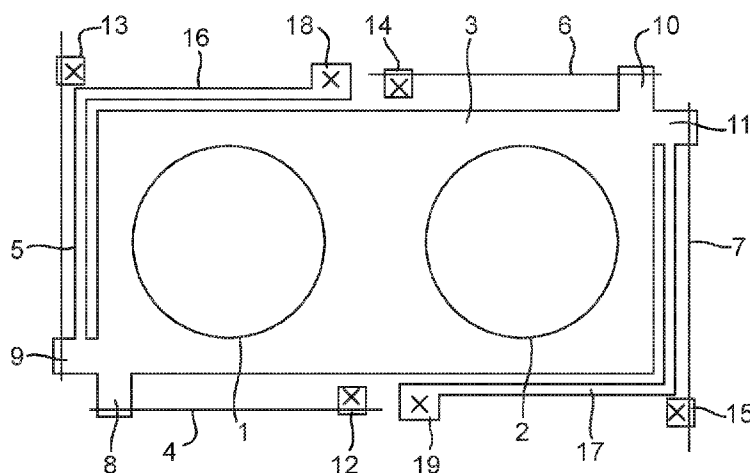
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(54) Title: DUAL CAMERA APPARATUS

Fig. 2



(57) Abstract: A dual camera apparatus for a mobile phone, comprising two lens carriers (1-2) fixed to a movable platform (3) connected to a support structure by at least four SMA wires (4-8) which can be selectively driven to provide OIS.



Dual camera apparatus

The present invention concerns a camera apparatus. More particularly, embodiments of the present invention relate to optical image stabilization (OIS) in a dual camera arrangement for mobile phones. It particularly concerns an OIS actuator
5 comprising shape memory alloy (SMA) wires.

Mobile phones typically contain one or more miniature cameras. In one known arrangement two cameras are mounted side by side. The two cameras may differ for example in their focal length or resolution or colour sensitivity, such that on combining signals from both cameras an enhanced image is obtained. Such a dual camera
10 arrangement is also known as a dual aperture camera.

Cambridge Mechatronics have previously disclosed SMA actuators for OIS in mobile phone cameras, for example in the co-owned international patent application WO2013/175197. The previously disclosed OIS actuator comprises 4 SMA wires and an electrical circuit, which includes a drive part and a resistance measurement sense part
15 which together provide closed loop control. The 4 SMA wires are disposed in a square arrangement around the lens carrier of the camera and are connected between the lens carrier and the support structure in such a way that they can be selectively driven to move the lens carrier in the plane perpendicular to the optic axis.

In a further aspect of the arrangement of WO2013/175197, the wires when driven
20 selectively produce no net torque around the optic axis, which has the benefit of simplifying the suspension arrangements and providing a compact design. In one embodiment, the four wires are of equal length and connected in opposite senses around the lens carrier, as illustrated in figure 1 (prior art).

In a dual aperture camera arrangement, it is possible to provide an OIS actuator
25 (such as that illustrated in figure 1) for each camera. This is a compact design but has the potential disadvantage that the two cameras may not move precisely in tandem, such that it becomes difficult to combine the two images they produce.

According to an aspect of the present invention, there is provided a camera
apparatus comprising: at least two image sensors fixed to a support structure; at least two
30 lens carriers each comprising one or more lenses arranged to focus images on the respective image sensors; a movable platform on which the lens carriers are fixedly mounted; and at least four shape-memory alloy, SMA, wires each connected at one end to the support structure and at a second end to the movable platform, wherein the SMA wires are capable of being selectively driven to move the movable platform relative to the

support structure to any position in a range of movement in the plane of the movable platform.

In the dual-camera of the invention, the two cameras (apertures) are mounted rigidly on a movable platform which is moved by a single SMA actuator to provide OIS. A single set of four SMA wires produces movement in the plane of the platform. Since the two cameras comprise optical lenses which are usually circular, a compact platform mounting two cameras side by side is necessarily longer in one dimension than the other. The set of four wires comprises two pairs of wires at diagonally opposite corners, the wires all being of similar length.

In a first aspect there is provided a camera apparatus comprising two image sensors fixed to a support structure; two lens carriers comprising one or more lenses arranged to focus images on the respective image sensors; a movable platform on which the two lens carriers are fixedly mounted and a total of four SMA wires each connected at one end to the support structure and at a second end to the movable platform wherein the four wires are of similar length and extend along the edges of the movable platform and the wires are capable of being selectively driven to move the movable platform relative to the support structure to any position in a range of movement in the plane of the movable platform.

In a second aspect there is provided a camera apparatus of the first aspect wherein the four SMA wires are arranged in two pairs, the first pair being fixed at a common location on the movable platform and the second pair being fixed at a diametrically opposite common location on the movable platform.

In a third aspect there is provided a camera apparatus of the first aspect wherein the movable platform is rectangular and the fixing points for the SMA wires are at two diametrically opposite corners.

In a fourth aspect there is provided a camera apparatus of the second aspect wherein the SMA wires are approximately the same length as the short side of the movable platform.

In a fifth aspect there is provided a camera apparatus of any of the first to fourth aspects further comprising a suspension system.

In a sixth aspect there is provided a camera apparatus of any of the first to fifth aspects wherein the suspension system comprises one of: L-shaped flexures connected between the movable element and the support structure; plain bearings; ball bearings.

In a seventh aspect there is provided a camera apparatus of the first aspect wherein the two image sensors are formed as two areas of a single image sensor component.

In an eighth aspect there is provided a camera apparatus of the first aspect comprising an additional one or more lens carriers and an equal number of additional image sensors.

5 In a ninth aspect there is provided a camera apparatus of the eighth aspect wherein the image sensors are formed as discrete areas of a single image sensor component.

In a tenth aspect there is provided a camera apparatus of the eighth or ninth aspect formed as an array camera.

In an eleventh aspect there is provided a camera apparatus of any of the first to tenth aspects wherein the SMA wires are driven to provide OIS.

10 In a twelfth aspect there is provided a camera apparatus of the first aspect wherein the four wires are of equal length.

In a thirteenth aspect there is provided a camera apparatus of the first aspect wherein the movable platform is rectangular in shape and the four wires extend along the four edges.

15 In a fourteenth aspect there is provided a camera apparatus of the thirteenth aspect wherein the two wires extending along the longer edges of the movable platform are thicker than the wires extending along the shorter edges of the movable platform.

In a fifteenth aspect there is provided a camera apparatus of the thirteenth aspect wherein there is an additional pair of SMA wires extending along the longer edge.

20 In a sixteenth aspect there is provided a camera apparatus comprising two image sensors fixed to a support structure; two lens carriers comprising one or more lenses arranged to focus images on the respective image sensors; a movable platform on which the two lens carriers are fixedly mounted and a total of four SMA wires each connected at one end to the support structure and at a second end to the movable platform and wherein the
25 four wires are of similar length and are arranged in pairs to pass between the lens carriers and the wires are capable of being selectively driven to move the movable platform relative to the support structure to any position in a range of movement in the plane of the movable platform.

30 To allow better understanding, and embodiment of the present invention will now be described by way of non-limitative example with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of the prior art;

Figure 2 is a schematic view of a camera apparatus according to an embodiment of the present invention;

Figure 3 is a schematic view of the camera apparatus shown in Figure 2;

Figures 4 to 6 are schematic views of camera apparatuses according to embodiments of the present invention; and

Figure 7 is a schematic view of the camera apparatus shown in Figure 6.

5 An embodiment of the invention is illustrated in figures 2 and 3. Figure 2 shows the dual camera from above while Figure 3 shows a cross section.

Figure 2 shows two cameras 1,2, which are rigidly mounted on a movable platform 3. The platform 3 is broadly rectangular in shape. The platform 3 is connected to a support structure 20 (not shown in Figure 2, but connection points on the support are marked with a cross) by four SMA wires 4-7. Each SMA wire 4-7 is held at its first end by a fixture 8-11 which is formed as an extension of the platform 3. Preferably the fixtures 8-11 form crimps holding the SMA wire. Each SMA wire 4-7 is held at its second end by a fixture 12-15 on the support structure (marked by a cross). The fixtures 12-15 are preferably crimps holding the SMA wire. There may be an additional suspension system suspending
10 the platform on the support structure. An example of a suitable suspension system is shown, comprising a pair of L-shaped flexures 16,17 extending from the platform 3 at fixtures 9 and 11 to the support structure at fixtures 18,19 (marked with a cross).

Figure 3 shows a cross section of the dual camera of Figure 2, illustrating the lens carriers 1,2, the movable platform 3, the support structure 20 and image sensors 21,22.

20 The SMA wires 4-7 form the OIS actuator. On heating to a suitable transformation temperature, SMA wire contracts. It can be seen from figure 2 that contraction of wire 4 causes the movable platform to move to the right (in the diagram) relative to the support structure, contraction of wire 6 causes movement to the left, contraction of wire 5 cause movement upwards and contraction of wire 7 causes movement downwards. Thus
25 differential contraction of all the wires allows the platform to be moved to any position with the x-y plane within the available range of movement. This movement is used to counteract camera shake, which may be detected for example by a gyro.

The four wires may be attached to the moving platform in any manner which allows the movement of the platform to any position in the plane of the platform within the
30 available range of movement. The range of movement is determined by the capacity of the SMA wires to contract. The particular arrangement of wires shown in Figure 2 is the preferred arrangement. The wires are effectively arranged in pairs, each pair attached to the moving platform at a common location. Thus, wires 4 and 5 are attached to the platform at crimps 8,9 located at the bottom left hand corner of the platform, while wires 6

and 7 are attached to the platform at crimps 10 and 11 at the diametrically opposite corner. Whilst this is a neat and compact arrangement, other wire arrangements are possible, for example the wire attachments at the platform need not be at a common location.

Each camera 1,2 may be a fixed focus or an autofocus camera unit. The dual-
 5 camera of the invention further comprises one or two image sensors mounted on the support structure, which image sensor(s) receive the images from the two apertures. The four SMA wires are preferably all the same length, as this facilitates accurate control. Optionally, each of the SMA wires has a length that is within 20%, optionally within 10%, optionally within 5%, and optionally within 1% of the length of each of the other SMA
 10 wires. Since the platform 3 is rectangular in shape, the SMA wires extend fully along the shorter sides but extend only partially along the two longer sides.

In the wire arrangement just described, there may be issues of rotation due to the different force couples created by the different wire separation between the two wire pairs. For some applications this may not be a problem. In addition, it may be possible to
 15 compensate for such a rotation by using different wire positions or diameters and modifying the control accordingly.

Further wire arrangements are shown in figures 4-7.

Figure 4 shows an arrangement whereby the wires 4,6 on the longer side are positioned centrally along the longer side, rather than towards a corner. The possibility of
 20 unwanted rotation arises as follows.

To simplify the control scheme it is preferable that the stress in all the wires 4,5,6,7 is similar, so that each SMA wire is operating in the same region. If the stress in each wire is the same and the wire diameter is the same, then the wire tension is also the same (tension $T = \text{stress} \times \text{area}$). If the tension in all the wires is the same then for a system such
 25 as that in figure 4 the couples exerted by the two opposing wire pairs do not balance, so this results in a rotation. The respective moments of the wire pairs 4,6 and 5,7 are given by tension T multiplied by separation D , that is:

$$M_{4,6} = T D_{4,6}; \quad M_{5,7} = t D_{5,7}$$

And since $D_{5,7}$ is larger than $D_{4,6}$, as indicated in figure 4, the moments are not
 30 equal resulting in a rotation.

To prevent such rotation, it is possible to make the tension in the two wire pairs 4,6 and 5,7 different. To balance the moments:

$$T_{4,6} D_{4,6} = T_{5,7} D_{5,7}$$

Thus the ratio of tensions needs to be the inverse of the ratio of separations:

$$T_{4,6}/T_{5,7} = D_{5,7}/D_{4,6}$$

One way to change the tension in the wire pairs but maintain the same stress is to use a different wire diameter for each pair. Since

$$\text{Tension} = \text{Stress} \times \text{Area}$$

5 the Tension can be changed whilst maintaining Stress if the Area is changed. For the example shown in Figure 4, where $D_{5,7}$ is greater than $D_{4,6}$, the tension in the wires 5 and 7 needs to be smaller than the tension in wires 4 and 6, so the area of wires 4 and 6 needs to be greater. This is achieved by using a larger diameter wire for the wires 4 and 6 on the longer side.

10 Another embodiment is shown in Figure 5, where an additional pair of wires is positioned in parallel on the longer side. There are now six wires, wires 5 and 7 on the shorter sides, and wires 48 and 49 on the first long side and wires 68 and 69 on the second long side. This serves to balance the moments in a similar manner to that described for figure 4.

15 In a second aspect of the invention, the wires are re-arranged to provide the benefit of reduced rotation. In this second aspect, the four SMA wires are not positioned along the edges of the platform 3 but are arranged in pairs passing between the two lens carriers.

The second aspect is illustrated in Figure 6. As before, two cameras 1,2 are mounted on a movable platform 3. The platform 3 is connected to a support structure 20 (not shown in Figure 6, but connection points to the support are marked with a cross) by four SMA wires 4-7 at fixtures 31-34 and four flexures 41-44 at fixtures 35-39. The SMA wires 4-7 are connected at their second end to the moving platform 3 by crimp fixtures 51-54. As shown in figure 6, the four wires are arranged as two pairs, wherein within each pair the wires are parallel to each other, and the two pairs are perpendicular to each other.

25 The wires within a pair overlap at the centre. Thus when wire 4 is activated it contracts to pull the platform diagonally down to the left; wire 5 when activated pulls the platform up and to the left; wire 6 when activated pulls the platform up and to the right; and wire 7 when activated pulls the platform down and to the right. As in the first aspect of the invention, the platform can be moved in the plane perpendicular to the optic axis to any

30 position by combinations of wire contraction. A perspective view of this arrangement is shown in figure 7.

In comparison with the first aspect, the crossed wire arrangement of the second aspect produces less rotation as the pitch between the wires is very much smaller. Furthermore, the wire attachment structures (fixtures 51-54) are located centrally between

the two cameras 1,2, freeing up the edges for location of the suspension springs (flexures 41-44). Four flexures can readily be accommodated, one at each corner, in symmetrical pairs. The distance of the flexures from the centre is relatively large (compared to that of the SMA wires) providing significant counter-rotation forces.

- 5 Optionally, each of the SMA wires has a length that is within 20%, optionally within 10%, optionally within 5%, and optionally within 1% of the length of the shorter edges of the movable platform.

Claims

1. A camera apparatus comprising:
at least two image sensors fixed to a support structure;
5 at least two lens carriers each comprising one or more lenses arranged to focus images on the respective image sensors;
a movable platform on which the lens carriers are fixedly mounted; and
at least four shape-memory alloy, SMA, wires each connected at one end to the support structure and at a second end to the movable platform,
10 wherein the SMA wires are capable of being selectively driven to move the movable platform relative to the support structure to any position in a range of movement in the plane of the movable platform.
2. The camera apparatus of claim 1, wherein the SMA wires extend along edges of the
15 movable platform.
3. The camera apparatus of claim 2, wherein at least one of the SMA wires extends along each of the edges of the movable platform.
- 20 4. The camera apparatus of claim 2 or 3, wherein four of the SMA wires are arranged in two pairs, the first pair being fixed to a first corner region of the movable platform and the second pair being fixed to a diametrically opposite second corner region of the movable platform.
- 25 5. The camera apparatus of any of claims 2 to 4, wherein the movable platform is rectangular having two shorter edges and two longer edges.
6. The camera apparatus of claim 5, wherein each of the longer edges of the movable platform has at least one of the SMA wires centrally positioned along it.
30
7. The camera apparatus of any of claims 2 to 6, wherein:
at least one of the SMA wires that extends along a longer edge of the movable platform is thicker than at least one SMA wire that extends along a shorter edge of the

movable platform.

8. The camera apparatus of any of claims 2 to 7, wherein a larger number of the SMA wires extend along each longer edge of the movable platform than along each shorter edge
5 of the movable platform.

9. The camera apparatus of any of claims 2 to 8, wherein at least two of the SMA wires extend along each longer edge of the movable platform.

10 10. The camera apparatus of claim 1, wherein at least four of the SMA wires extend in directions that extend between the lenses of the lens carriers.

11. The camera apparatus of claim 10, wherein the at least four SMA wires are arranged in pairs, each pair comprising two of the SMA wires extending parallel to each
15 other.

12. The camera apparatus of claim 11, wherein the SMA wires of each pair overlap each other when viewed in a direction perpendicular to the direction in which the SMA wires extend.
20

13. The camera apparatus of claim 10 or 11, wherein the SMA wires of one pair extend perpendicularly to the SMA wires of another pair.

14. The camera apparatus of any preceding claim, wherein each of the SMA wires has a
25 length that is within 20% of the length of each of the other SMA wires.

15. The camera apparatus of any preceding claim, wherein the movable platform is rectangular having two shorter edges and two longer edges.

30 16. The camera apparatus of claim 15, wherein each of the SMA wires has a length that is within 20% of the length of the shorter edges of the movable platform.

17. The camera apparatus of claim 15 or 16, wherein each of the SMA wires has a length that is shorter than the length of the longer edges of the movable platform.

18. The camera apparatus of any preceding claim, wherein the points at which the SMA
5 wires are fixed to the movable platform are at diametrically opposite corners of the movable platform.

19. The camera apparatus of any preceding claim, further comprising a suspension system for suspending the movable platform relative to the support structure.

10

20. The camera apparatus of claim 19, wherein the suspension system comprises at least one of:

at least one L-shaped flexure connected between the movable platform and the support structure;

15 plain bearings; and
ball bearings.

21. The camera apparatus of claim 20, wherein each L-shaped flexure is within the plane of the movable platform.

20

22. The camera apparatus of any preceding claim, wherein the image sensors are formed as discrete areas of a single image sensor component.

23. The camera apparatus of any preceding claim, comprising three or more lens
25 carriers and a corresponding number of image sensors.

24. The camera apparatus of claim 23, formed as an array camera.

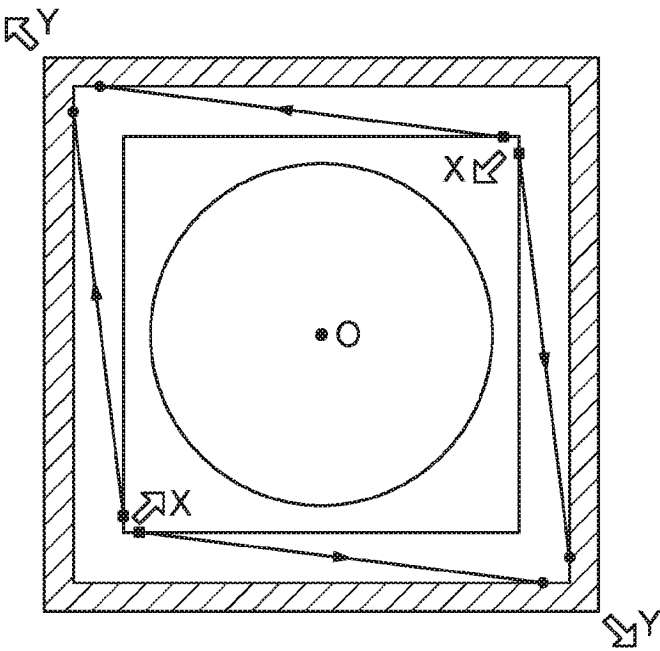
25. The camera apparatus of any preceding claim, wherein the SMA wires are
30 configured to be driven to provide optical image stabilization, OIS.

26. The camera apparatus of any preceding claim, comprising an electrical circuit for providing closed-loop control of the SMA wires for positioning the movable platform

relative to the support structure.

27. A mobile phone comprising the camera apparatus of any preceding claim.

Fig. 1



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Fig. 2

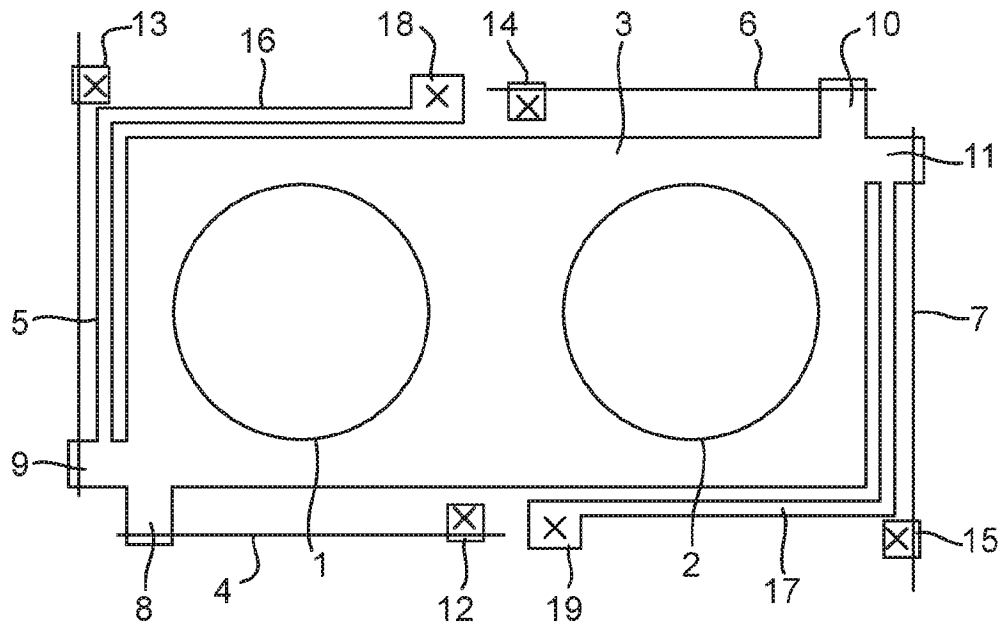
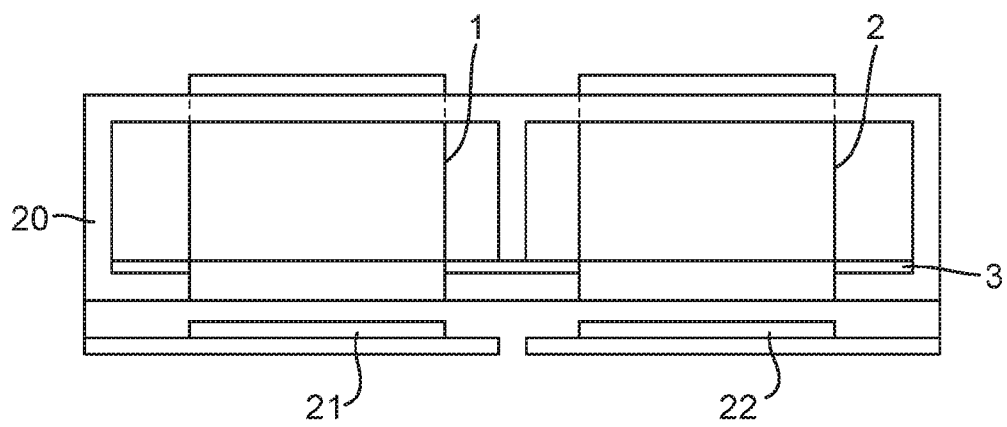


Fig. 3



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Fig. 4

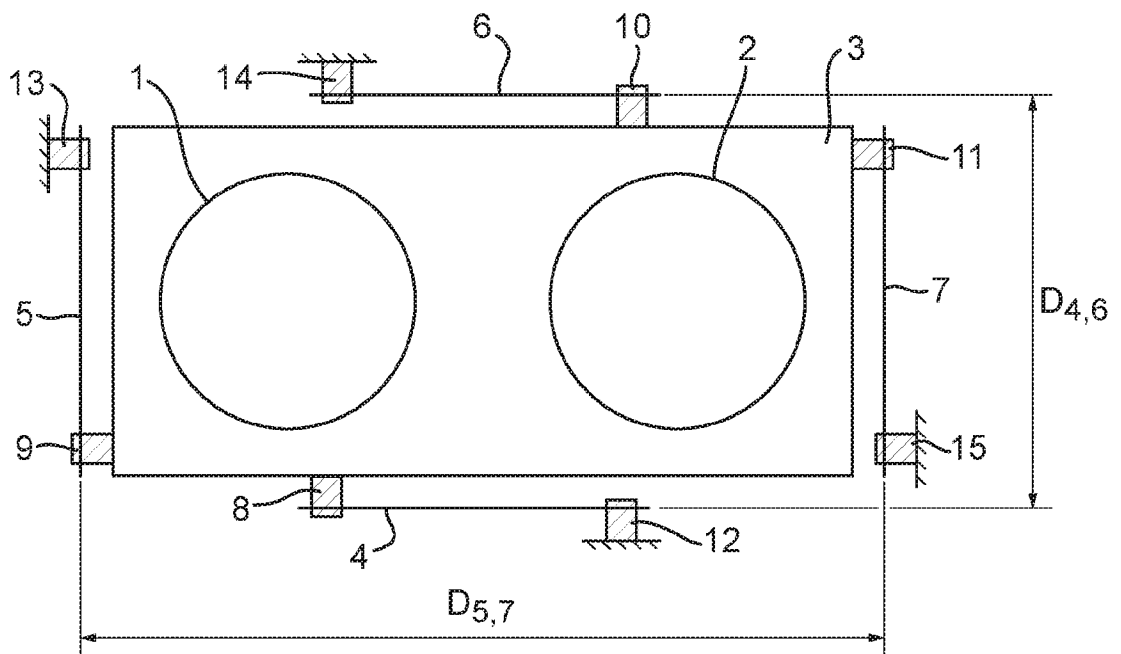
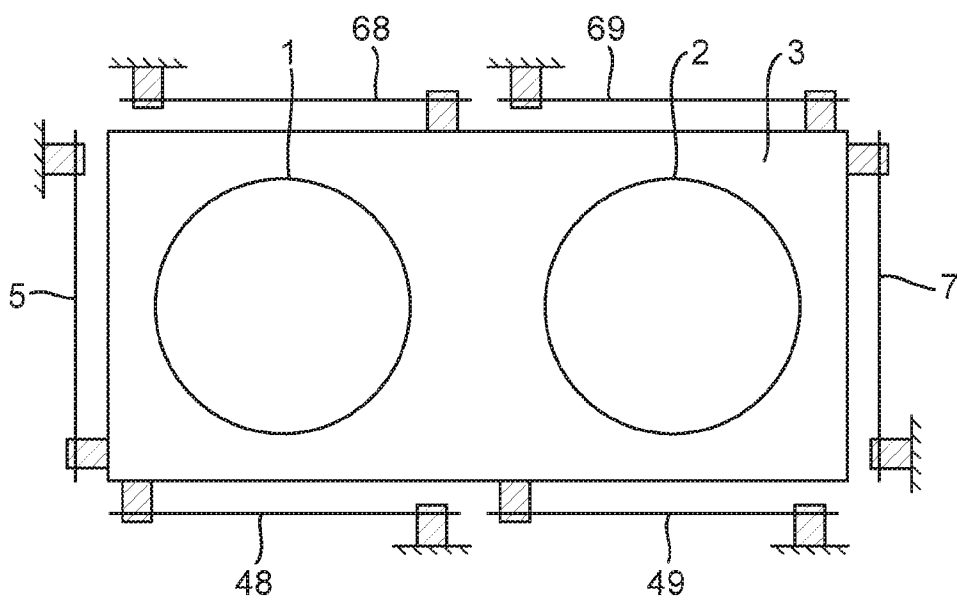


Fig. 5



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Fig. 6

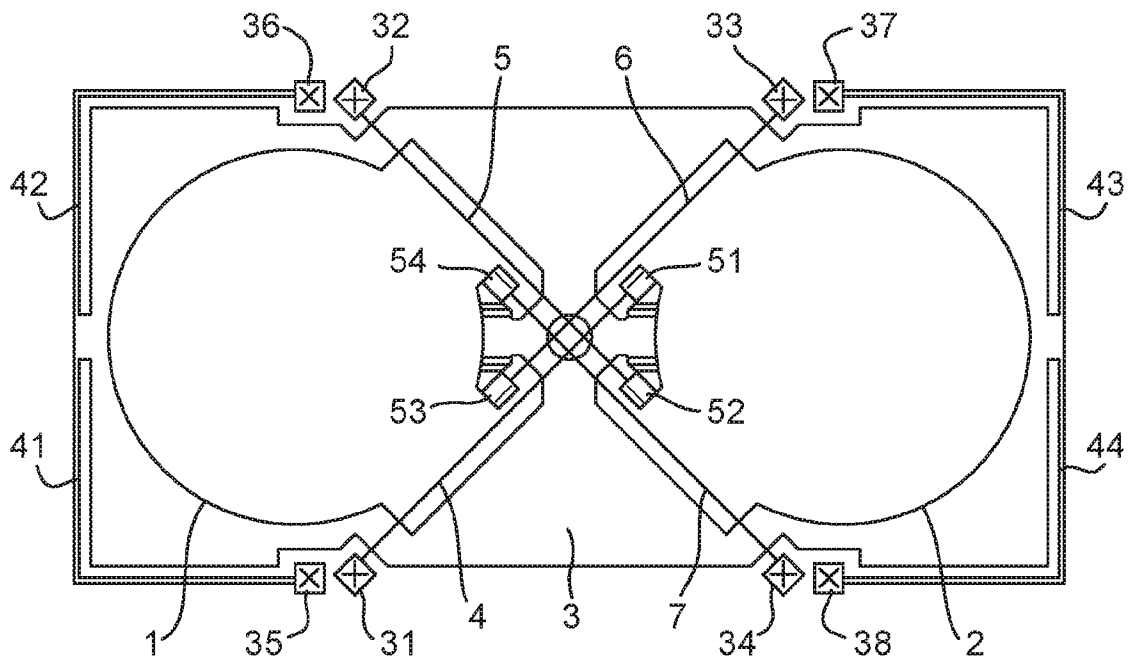
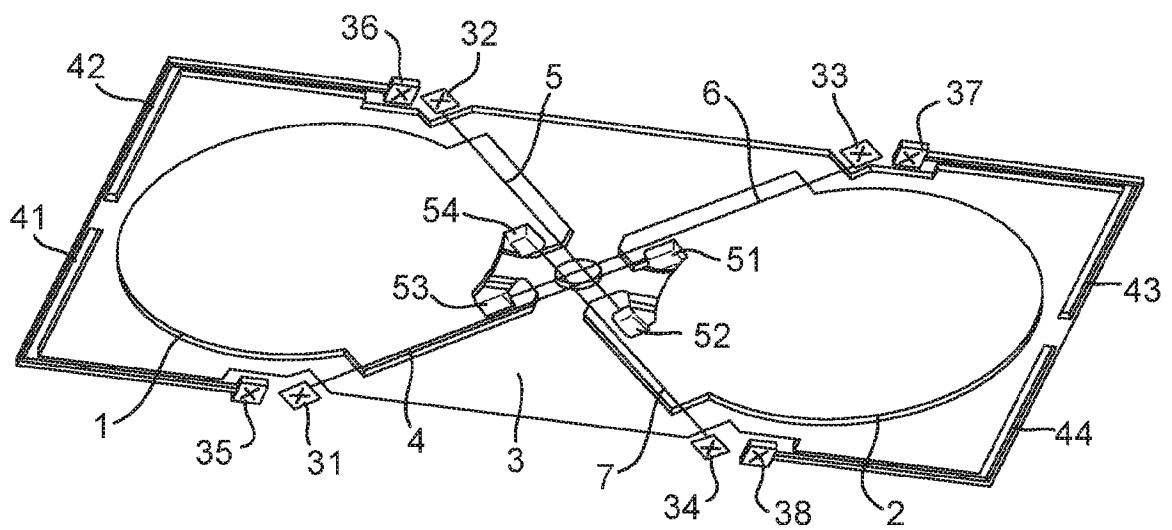


Fig. 7



INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2017/052330

A. CLASSIFICATION OF SUBJECT MATTER
INV. G03B17/00 G02B27/64
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)
G03B G02B

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	WO 2014/083318 A1 (CAMBRIDGE MECHATRONICS LTD [GB]) 5 June 2014 (2014-06-05) page 6, line 15 - page 9, line 5; figures 1-5 -----	1-27
X	WO 2013/175197 A1 (CAMBRIDGE MECHATRONICS LTD [GB]) 28 November 2013 (2013-11-28) cited in the application page 3, line 18 - page 8, line 4; figures 1-5 -----	1-27
X	WO 2016/009200 A1 (CAMBRIDGE MECHATRONICS LTD [GB]) 21 January 2016 (2016-01-21) page 5, line 19 - page 10, line 10; figures 1-3 ----- -/-	1-27



Further documents are listed in the continuation of Box C.



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Date of the actual completion of the international search

11 October 2017

Date of mailing of the international search report

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NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Tomezzoli, Giancarlo

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2017/052330

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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