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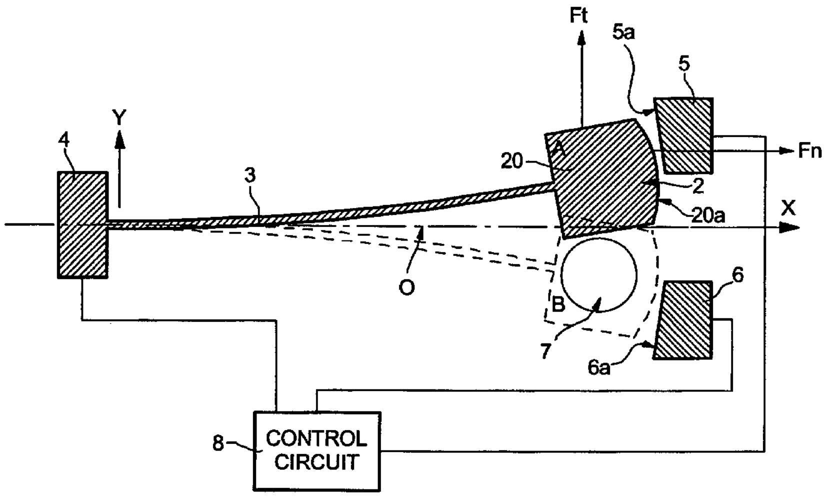

(57) Abstract: There is described a switching device comprising a mobile element (2) that is able to at least move back and forth along a defined trajectory between a zero position (O) and at least one predetermined switching position (A, B), an elastic member (3) connecting the mobile element to a base (4) and at least one stationary actuating electrode (5, 6) located in the vicinity of the predetermined switching position for producing electrostatic forces to cause the mobile element to move to and/or away from the predetermined switching position. The stationary actuating electrode is disposed to act on at least one edge (20a) of the mobile element which is substantially parallel to the mobile element's trajectory. The geometry of the mobile element, elastic member and actuating electrode is such that the mobile element cannot come into contact with the actuating electrode and that the switching position is defined by an equilibrium point (E) between lateral electrostatic forces produced on the mobile element by the stationary actuating electrode and mechanical springs forces produced by the elastic member.

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SWITCHING DEVICE, IN PARTICULAR FOR OPTICAL APPLICATIONS

The present invention generally relates to micro electro-mechanical systems or so-called MEMS. More particularly, the present invention relates to a switching device comprising a mobile element that is able to move back and forth along a defined trajectory between a zero position and at least one predetermined switching position, an elastic member connecting the mobile element to a base, and at least one stationary actuating electrode located in the vicinity of the said at least one predetermined switching position. The present invention also relates to a method for operating such a switching device and a switching unit that comprises at least one such switching device.

A very wide variety of micromechanical structures that influence or switch, respectively, the paths of optical beams are known. The purpose of such structures is the control, processing, and/or storage of data from pixel-based images.

European Patent Application No. 0 510 629 discloses a deflectable device based on so-called deformable mirror devices, or DMDs, which is also used as a shutter device for selectively interrupting or altering the passage of a light beam. As for other types of DMDs, the device is provided with a controllable screen plate which can either rotate around an axis or move towards the substrate's plane in a piston-like fashion by means of adequate torsion beams, cantilever beams or hinges. Other examples of DMDs may for instance be found in U.S. Patent No. 4,229,732 and U.S. Patent No. 5,142,405.

U.S. Patent No. 5,794,761 discloses a switching device that may be used as a micro-shutter for optical applications. Figure 1 is a schematic view of this switching device. According to this document, mobile element 2, or swinging element, is able to move between two end positions A and B to selectively interrupt the passage of a light beam through an opening 7 (located in end position B) provided in the substrate of the switching device. Electrodes 5, 6 are placed in the vicinity of end positions A and B. A control circuit 8 is provided to generate electrostatic forces of attraction and/or repulsion for switching the swinging element 2 between the two end positions. The swinging element 2 is attached to the substrate in an elastic manner (for example by means of a flexible beam 3 which is clamped at one of its end to an anchoring point or base 4). More particularly, according to this document, beam 3 is designed in such a way that an elastic return force which tends towards a zero position O has, in an essential amplitude range, a higher value than the electrostatic force of attraction generated by the control circuit and the electrodes. Accordingly, the characteristics of the switching devices, such as its response time, are mainly determined by the mechanical properties of the structure.

The article "Electrostatic Microshutter Arrays in Polysilicon", G. Perregaux et al., published in "CSEM Scientific and Technical Report 1999", page 99, discloses an improvement of the above-mentioned switching device. Figure 2 is a schematic view of this other switching device. Electrodes 5, 6 are provided along the whole length of the flexible beam 3 which connects the swinging element 2 to the substrate. Stoppers 9 are further provided on both sides of flexible beam 3 along its length in order to avoid short-circuits between the beam and the electrodes.

Other types of optical micro-shutter devices may be found in U.S. Patent No. 4.383.255 or U.S. Patent No. 4,564,836.

According to all of the above prior art solutions, the switching device is actuated by means of attractive forces, i.e. the electrodes are disposed laterally with respect to the mobile element's trajectory so as to produce electrostatic forces which are substantially normal to the cooperating edges of the electrodes and of the swinging element. Stoppers are therefore typically required to limit the displacement of the mobile element as well as prevent any short-circuit between the electrodes and the mobile element.

The contact between the polysilicon surface (or other material) and the stoppers may lead to extensive wear and debris production and can eventually lead to sticking of the mobile element. The so-called "stiction problem" (which also encompasses problems due to capillarity forces or organic and non-organic contamination) is a well-known and very actual and critical problem with micromechanical switching devices. In the small dimensions, the sticking effect increases with the inverse of the scale down factor, with a preponderance effect due to humidity, surface trapped charges or other proximity forces (such as quantum Van de Walls forces). These sticking forces are in the same order of magnitude than the activation forces (around 0.2 N/ m^2). They therefore have significant influence on the reliability of such systems.

In order to overcome this problem, a solution is to conceive structures without stoppers. Without stoppers the control of the displacements of the switching device's mobile element highly depend on the drive level or on an auto-blocking elastic effect such as buckling. Structures using the buckling effect are however very sensitive to technology tolerances and are therefore expensive and complicated to manufacture.

Another solution is to chemically treat the device surfaces and for instance coat the device with an additional layer such as a polymer. This solution however increases the fabrication complexity of the device as well as its costs. In addition, excessive wear of this coating layer can nevertheless give rise to the above stiction problem.

There exists therefore a need for simpler and more reliable solutions to overcome the above-mentioned stiction and short-circuit problems. A principal object of the present invention is thus to provide a solution that is not prone to stiction problems and that is as much as possible independent of the drive and technological tolerances to control the displacements of the mobile element of the switching device.

Another object of the present invention is to provide a solution that is not unnecessarily complicated to manufacture.

A secondary object of the present invention is to provide a switching device that can be arranged in a matrix configuration.

Accordingly, there is provided a switching device the features of which are listed in claim 1.

There is also provided a switching unit comprising a number of such switching device, as well as a method for actuating a switching device the features of which are listed in claim 9.

Other advantageous embodiments of the invention are the object of the dependent claims.

According to the present invention, and in contrast to prior art solutions, the actuating electrodes are not disposed to act laterally on the mobile element so as to produce attractive electrostatic forces but act on a frontal edge of the mobile element (that is an edge which is substantially parallel to the mobile element's trajectory). This driving principle may be called "Edge Electrostatic Drive", that is the movement of the mobile element is not caused by attractive forces generated by the actuating electrodes (as in the prior art solutions), but is rather caused by lateral forces which are substantially parallel to the cooperating frontal edges of the stationary electrodes and of the electrode of the mobile element.

In the scope of the present invention, an attractive electrostatic force shall mean an electrostatic force which tends to bring the cooperating edges of the electrodes nearer (or, conversely, which tends to separate these cooperating edges), whereas a lateral electrostatic force shall mean an electrostatic force which tends to align the cooperating edges of the electrodes one with respect to the other.

According to the present invention, the switching device can truly be designed as a contact-less structure which is not affected by the above-mentioned stiction problems. Indeed, stoppers are not anymore required to define the end positions of the mobile element. As a matter of fact, the mobile element is auto-stabilized in its selected position due to the inversion of the forces resulting from the sum of the lateral electrostatic forces and mechanical spring forces exerted on the device's mobile element.

According to the present invention, the geometry of the device is selected to enhance the contributions of lateral electrostatic forces. Furthermore, in contrast to prior art solutions, the device's switching positions are determined by an equilibrium point between the lateral electrostatic forces produced by the electrodes on the device's mobile element and mechanical spring forces produced by the elastic member that connects the mobile element to the device's base member. The force resulting from the sum of these lateral electrostatic force and mechanical spring force presents an inversion point around this equilibrium point.

More particularly, according to one embodiment of the invention, the switching device is used as a shutter device for selectively interrupting the passage of a light beam, the switching device being provided with an opening, which is either open or closed by a screen plate.

It should be pointed out that the present invention can advantageously be applied in optical application to interrupt, modulate or control the passage of light beams but is however not limited to that particular type of applications.

Other aspects, features and advantages of the present invention will be apparent upon reading the following detailed description of non-limiting examples and embodiments made with reference to the accompanying drawings, in which :

- Figure 1 schematically shows a first switching device of the prior art ;
- Figure 2 schematically shows a known improvement of the switching device of Figure 1 ;
- Figure 3 schematically shows a first embodiment of the switching device according to the present invention ;
- Figure 4 schematically illustrates the evolution of the lateral electrostatic force and of the mechanical spring force exerted on the switching device's mobile element according to a preferred embodiment of the present invention ; and
- Figure 5 schematically shows a two-dimensional switching unit comprising an array of four switching devices similar to the switching device of Figure 3 .

Figure 6 schematically shows a second embodiment of the switching device according to the present invention ;

Figure 6a schematically shows a variant of the embodiment of Figure 6 ;

Figure 7 schematically shows a third embodiment of the switching device according to the present invention ,

Figure 8 schematically shows a fourth embodiment of the switching device according to the present invention,

Figure 9 schematically shows a fifth embodiment of the switching device according to the present invention comprising comb-shaped electrode structures and where

Figure 10 illustrates different applicable shutter blade structures according to the invention.

Detailed description

Figure 3 schematically shows a switching device constituting a first embodiment of the present invention. A mobile element 2 comprising a screen in the form of a plate 20 is attached to one end of an elastic rod or beam 3. The other end of the elastic beam 3 is clamped in an anchoring point or base 4.

As illustrated in Figure 3, the elastic beam 3 extends, in a zero or rest position O, along an axis "x" indicated here for the purpose of explanation. Screen plate 20 and beam 3 form an oscillating mechanical system wherein screen plate 20 can move back and forth, here between two predetermined switching positions indicated by references A and B, along a direction substantially parallel to an axis "y" perpendicular to axis "x". It will be appreciated that only one or more than two predetermined switching positions could be defined. According to this embodiment, one will actually note that the screen plate's trajectory follows a curved path and is not strictly speaking parallel to axis y. One will however also note that the degree of curvature of the trajectory of screen plate 20 is dependent on the actual length of beam 3 and can thus be limited provided that the beam length is sufficiently high as compared to the global course of the mobile element. For the purpose of simplification, it will be held that the mobile element's trajectory is substantially parallel to axis y.

Stationary actuating electrodes 5 and 6 for displacing screen plate 20 are respectively disposed in the vicinity of positions A and B. Actuating electrodes 5, 6 and screen plate 20, which is also covered by an electrode, are electrically connected to a control circuit 8 which can switch the switching device. Each one of electrodes 5, 6 comprises a so-called frontal edge 5a, 6a which cooperates with a frontal edge 20a of screen plate 20. In the rest position O, the frontal edge 20a of screen plate 20 may partially overlap the frontal edges of actuating electrodes 5, 6.

In the vicinity of actuating electrode 6, there is an opening 7 which is exposed when screen plate 20 is in end position A and which is covered when screen plate 20 is in end position B. In this way, a path for optical light beams can be opened or interrupted so that the switching device acts as an optical shutter.

According to this first embodiment of the invention and in contrast to the prior art solutions, the electrodes are not disposed to act on the lateral edge of the screen plate 20 (that is an edge which is substantially perpendicular to the screen plate's trajectory) but act on the frontal edge 20a of screen plate 20, that is an edge which is substantially parallel to the screen plate's trajectory, or, in other words, an edge which extends along a direction substantially parallel to axis "y" in Figure 3. This driving principle may be called "Edge Electrostatic Drive", that is the movement of screen plate 20 is not caused by attractive forces generated by the actuating electrodes (as in the prior art solutions), but is rather caused by lateral forces which are substantially parallel to the cooperating frontal edges of the stationary electrodes and of the electrode of the screen plate.

It may be demonstrated that lateral electrostatic forces exerted on two electrodes in a parallel configuration are inverse proportional to the gap existing between these two electrodes.

According to the present invention, it will be noted that the switching device is auto-stabilized by saturation in the electrostatic drive, that is the structure does not require any stoppers to delimit the end positions of screen plate 20. This constitutes a considerable advantage with respect to prior art solutions since sticking of the structure against the stoppers as well as short-circuit or collapse of the structure against the actuating electrodes are thereby prevented. Stoppers may nevertheless be optionally provided in order to protect the structure against external shocks.

More particularly, the geometry of the mobile element, elastic member and stationary actuating electrodes is selected so that the mobile element cannot come into contact with either one of the actuating electrodes and that the predetermined switching positions are each defined by an equilibrium point between the lateral electrostatic forces produced on the mobile element by the stationary actuating electrodes and the mechanical springs forces produced by the elastic member. The force resulting from the sum of these lateral electrostatic forces and mechanical spring forces has opposite directions around this equilibrium point.

Figure 4 schematically illustrates the evolution of the lateral electrostatic forces (curve a) and mechanical spring forces (curve b, which is a substantially linear curve) in the vicinity of the equilibrium point (indicated by reference E) according to a preferred embodiment of the invention. Preferably, the geometry of the mobile element, elastic member and stationary actuating electrodes is selected in such a way that the lateral electrostatic forces exhibit a steep drop of intensity close to the equilibrium point. This property is also the basis that allows this structure to be used in a matrix configuration, as schematically illustrated in Figure 5.

Furthermore, the attractive electrostatic forces which are still generated by the actuating electrodes produce a reaction on screen plate 20 which may be qualified as "lateral surfing". Indeed, the attractive electrostatic forces tend to attract screen plate 20 towards the actuated electrode. Since screen plate 20 is however retained by beam 3, plate 20 is subjected to a torque which further pulls mobile element 2 to its selected position.

In the predetermined positions A, B, oscillation of screen plate 20 around its selected position is advantageously damped by air as well as electrostatically due to the inversion of the force resulting from the sum of the lateral electrostatic force and mechanical spring force exerted on screen plate 20. It must be stressed that this damping is achieved according to the present invention since screen plate is essentially moved due to contributions of lateral electrostatic forces and that such a damping effect could not be achieved with conventional systems based on attractive-type driving principles.

Frontal edge 20a of screen plate 20, that is the outermost edge of screen plate 20, is preferably designed to have a curved profile so that the gap between screen plate 20 and the electrodes 5, 6 can be reduced, thereby increasing the sensitivity of the device, and without fearing for short-circuits to happen between the actuating electrodes and the mobile element.

It will be appreciated that a decrease in the gap between the actuating electrodes 5, 6 and screen plate 20 increases the sensitivity of the switching device. In that regard, the drive sensitivity profile can easily be adjusted by an adequate choice of the electrode geometry. In Figure 3, actuating electrodes 5, 6 are shown to have an oblique edge, but it will clearly be understood that these electrodes may exhibit any other suitable profile such as for instance a curved profile essentially matching the envelope of the screen plate axis extremity, or even a stepped profile.

Furthermore, it will clearly be understood that the shape of the blade 2 and the frontal edge 20a may exhibit any other suitable profile matching the electrodes and an optimised evolution of the forces acting on the mobile element. See for example fig. 10a to fig. 10d.

The above switching device is typically produced in a substrate (made of, for example, silicon or a transparent material such as glass) according to surface micro-machining techniques well-known in the art. For instance, the free-standing structures (such as screen plate 20 and beam 3 in Figure 3) may typically be fabricated using so-called sacrificial layer techniques, that is the movable structure of the switching device is firstly formed on top of a sacrificial layer or spacer and portions of this sacrificial layer are subsequently removed to release the required parts of the switching device.

Screen plate 20 is essentially square (having a surface area of approximately 35 x 35 m^2 and a thickness of about 2 m) and is attached to the end of beam 3 (having a length of about 350 to 400 m and a section of about 2.5 x 2 m^2). Screen plate 20 and beam 3 can be made, for example, of metal or polysilicon (or any other crystalline or polycrystalline material). Beam 3, being long and thin, is elastically deformable so as to allow a swinging movement of screen plate 20 in a plane substantially parallel to the substrate's plane.

In the above example, actuating electrodes 5, 6 cooperate with the frontal edge 20a of screen plate 20 (the outermost edge of screen plate 20). It will however be appreciated that the driving principle according to the present invention can be applied to any other suitable edge of mobile element 2 provided that this edge is substantially parallel to the mobile element's trajectory.

The switching device according to the present invention will preferably be used not individually but in combination with other identical or possibly different devices to form an array. These switching devices may be arranged to form a regular two-dimensional grid, such as a rectangular or honeycombed arrangement, and are typically addressed using row and column lines. For the purpose of explanation, Figure 5 schematically shows four switching devices S1 to S4 (similar to the switching device of Figure 3) which are arranged in two rows and two columns. The two actuating electrodes of switching devices S1 and S3 are connected together by two column lines A1 and B1, respectively. Similarly, the two actuating electrodes of switching devices S2 and S4 are connected together by two column lines A2 and B2. The bases of switching devices S1 and S2, on the one hand, and of switching devices S3 and S4, on the other hand, are connected together on a row line R1 and R2, respectively.

It will be understood that each switching device can be addressed individually by selectively activating the adequate row and column lines. It will also be appreciated that the specific arrangement of Figure 5 is purely illustrative and is in no way limitative, and that the switching devices will in practice be organized in such way as to take as little space as possible to increase the density of such devices on the substrate.

Having described the invention with regard to certain specific embodiments, it is to be understood that these embodiments are not meant as limitations of the invention. Indeed, various modifications and/or adaptations may become apparent to those skilled in the art without departing from the scope of the annexed claims. For instance, the proposed embodiments are not necessarily limited to structure comprising a mobile element able to be moved back and forth between only two end positions. Since no stoppers are anymore required, it could perfectly be envisaged to control the mobile element to switch between three or more predetermined positions provided that the device is equipped with the adequate number of electrodes.

Fig. 6 schematically shows a second embodiment of the present invention. The switching device illustrated in this Figure essentially differs from the switching device of Figure 3 in that the elastic member, which connects screen plate 20 to base 4, (which here consists of two distinct bases) consists of a folded beam structure having, in this particular example, essentially an "E" shape. This folded beam structure comprises a first pair of beams 30 (a single beam could however be used) extending from base 4 to an intermediate member 32 in a direction substantially parallel to the plane of the substrate. A second beam 3 (which essentially corresponds to beam 3 of Figure 3) extends from intermediate member 32 to screen plate 20 in a second direction substantially opposite to the first direction. The geometry of the folded beam structure which elastically connects screen plate 20 to base 4 may take any other adequate form than that illustrated in Figure 5. In particular, intermediate member 32 may be reduced in size so as to save some space on the substrate's surface, and first beams 30 may extend in a slightly oblique manner as shown in Figure 6a. This latter configuration allows a higher density of switching devices to be accommodated on the same substrate.

Figure 7 shows a third embodiment of the present invention. In this example switching device 1 is provided with means for guiding screen plate 20 in a substantially linear way. To this end, the single beam structure of Figure 3 is replaced by a parallel or pantograph-like structure. This parallel beam structure can easily be realised by means of a pair of parallel flexible beams indicated by reference numerals 35 and 36. Such a parallel configuration causes screen plate 20 to be guided linearly and not anymore rotated as this is the case with the above-described solutions. The frontal edge 20a of screen plate 20 does not therefore require to be curved and the gap between screen plate 20 and actuating electrodes 5. 6 can be kept almost constant.

The parallel structure which has just been described can also be combined with the folded beam structure of Figure 6 as illustrated by the fourth embodiment of Figure 8. The elastic member connecting screen plate 20 to the base 4 there comprises a first pair of parallel flexible beams 33, 34 extending from base 4 (there are actually two bases in this example) to intermediate member 32 and a second pair of parallel flexible beams 35, 36 extending from intermediate member 32 to screen plate 20 in an opposite direction. Here again, the gap between screen plate and actuating electrodes 5, 6 can be kept constant.

Figure 9 shows an example of the switching device according to the present invention which is equipped with comb-shaped electrode structures, this device being essentially similar to the device of Figure 8. Comb-shaped structures 25 are provided on each side of mobile element 2 and interact with comb-shaped structures 55 and 65 provided on actuating electrodes 5 and 6 respectively. Each tooth of comb-shaped structures 25, 55 and 65 extends in a direction substantially parallel to the mobile element's trajectory, and comprises an end portion 25a, 55a, 65a of greater dimensions or diameter than that of the portion which connects the tooth to mobile element 2 or actuating electrodes 5, 6, respectively. Accordingly, tangential electrostatic forces will also be produced by actuating electrodes on each tooth of mobile element 2.

In the example of Figure 9, the pair of parallel flexible beams 33, 34 which connect base 4 to intermediate member 32 are located between the second pair of parallel flexible beams 35. 36 that connect intermediate member 32 to mobile element 2. Base 4 can therefore advantageously act as a security stopper against external shocks.

An advantage of the switching device of Figure 9 resides in the fact that high air damping of the structure can be achieved between the teeth of the comb-shaped structures. Associated with the electrostatic brake which is increased by the comb-shaped structures, this air damping contributes to reducing the response time of the device.

Figs. 10a to 10d illustrate different shutter blade 16 designs within the scope of the invention.

It should be noted that the “corners” of the shutter blade 16 in a preferred embodiment of the invention should be curved/rounded in order to minimize the size and weight of the blade.

An optimal blade design with respect to weight/form facilitates quicker and easier acceleration of the blade once activated by the associated electrodes.

Still, it should be noted that the blade should be able to cover/block an associated transmission path which is not necessarily circular according to the invention.

In other words, according to the invention, the light transmission path in the shutter substrate may have a non-circular cross-section, if so desired.

CLAIMS

1. Switching device comprising :

- a mobile element (2) that is able to move back and forth along a defined trajectory between a zero position (O) and at least one predetermined switching position (A, B) ;

- an elastic member (3) connecting said mobile element (2) to a base (4), said elastic member (3) allowing said mobile element (2) to at least move back and forth between said zero position (O) and said at least one predetermined switching position (A, B) ; and

- at least one stationary actuating electrode (5, 6) located in the vicinity of said at least one predetermined switching position (A, B) for producing electrostatic forces to cause said mobile element (2) to move to and/or away from said at least one predetermined switching position (A, B),

wherein said at least one stationary actuating electrode (5, 6) is disposed to act on at least one edge (20a) of said mobile element (2) that is substantially parallel to the mobile element's trajectory, and wherein the geometry of said mobile element (2), said elastic member (3) and said at least one stationary actuating electrode (5, 6) is such that said mobile element (2) cannot come into contact with said actuating electrode (5, 6) and that said at least one predetermined switching position (A, B) is defined by an equilibrium point (E) between lateral electrostatic forces produced on said mobile element (2) by said at least one stationary actuating electrode (5, 6) and mechanical springs forces produced by said elastic member (3), the force resulting from the sum of said lateral electrostatic forces and said mechanical spring forces having opposite directions around said equilibrium point (E).

2. Switching device according to claim 1, wherein the geometry of said mobile element (2), said elastic member (3) and said at least one stationary actuating electrode (5, 6) is such that said lateral electrostatic forces exhibit a steep drop of intensity close to said equilibrium point (E).

3. Switching device according to claim 1, wherein said switching device is produced in the form of a micro-mechanical structure, said device further

comprising a substrate (10), said mobile element (2), said elastic member (3) and said actuating electrode (5, 6) being micro-machined into said substrate.

4. Switching device according to claim 3, wherein said substrate (10) includes a crystalline or polycrystalline material such as silicon or polysilicon.

5. Switching device according to claim 3, wherein said substrate includes metal.

6. Switching device according to any one of claims 3 to 5, wherein said mobile element (2) comprises a screen plate (20) which is able to move in a plane substantially parallel to the plane of said substrate (10).

7. Switching device according to claim 6, wherein an opening (7) is provided in the plane of said substrate (10), said opening (7) being either closed by said screen plate (20) or open depending on whether said mobile element is in said predetermined switching position (B).

8. Switching unit comprising a plurality of switching devices according to any one of claims 1 to 7.

9. Switching device according to any one of claims 1 to 8, wherein said elastic member (3, 30, 32: 32. 33. 34, 35, 36) comprises a folded beam structure comprising at least a first beam (30; 33. 34) extending from said base (4) to an intermediate member (32) in a first direction substantially parallel to the plane of said substrate (10) and at least a second beam (3; 35, 36) extending from said intermediate member (32) to said mobile element (2) in a second direction substantially opposite to said first direction.

10. Switching device according to any one of claims 1 to 9, wherein said elastic member (35, 36; 32, 33. 34, 35, 36) comprises a parallel or pantograph-like structure for guiding said mobile element (2) so that its trajectory is substantially linear.

11. Switching device according to any one of claims 1 to 10, wherein said mobile element (2) and said actuating electrodes (5, 6) each comprise a comb-shaped structure (25, 55, 65) including a plurality of teeth extending in a direction

substantially parallel to the mobile element's trajectory, each tooth comprising an end portion (25a, 55a, 65a) and a base portion connecting said first portion to said mobile element (2) or said actuating electrode (5, 6), respectively, said base portion being of smaller diameter than said end portion (25a, 55a, 65a).

12. Switching device according to claim 11, wherein said comb-shaped structures (25, 55, 65) are designed so that air damping between said teeth is achieved.

13. Method for actuating a switching device comprising :

- a mobile element (2) that is able to move back and forth along a defined trajectory between a zero position (O) and at least one predetermined switching position (A, B) ;
- an elastic member (3) connecting said mobile element to a base (4), said elastic member allowing said mobile element to at least move back and forth between said zero position (O) and said at least one predetermined switching position (A, B) ; and
- at least one stationary actuating electrode (5, 6) located in the vicinity of said at least one predetermined switching position (A, B) for producing electrostatic forces to cause said mobile element (2) to at least move to and/or away from said at least one predetermined switching position (A, B),

said method being characterized in that it comprises the steps of :

- placing said stationary actuating electrodes (5, 6) to act on at least one edge (20a) of said mobile element (2) which is substantially parallel to the mobile element's trajectory ; and
- selecting the geometry of said mobile element (2), said elastic member (3) and said at least one stationary actuating electrode (5, 6) so that said mobile element (2) cannot come into contact with said actuating electrode (5, 6) and that said at least one predetermined switching position (A, B) is defined by an equilibrium point between lateral electrostatic forces produced on said mobile element (2) by said at least one stationary actuating electrode (5, 6) and mechanical springs forces produced by said elastic member (3), the force resulting from the sum

of said lateral electrostatic forces and said mechanical spring forces having opposite directions around said equilibrium point.

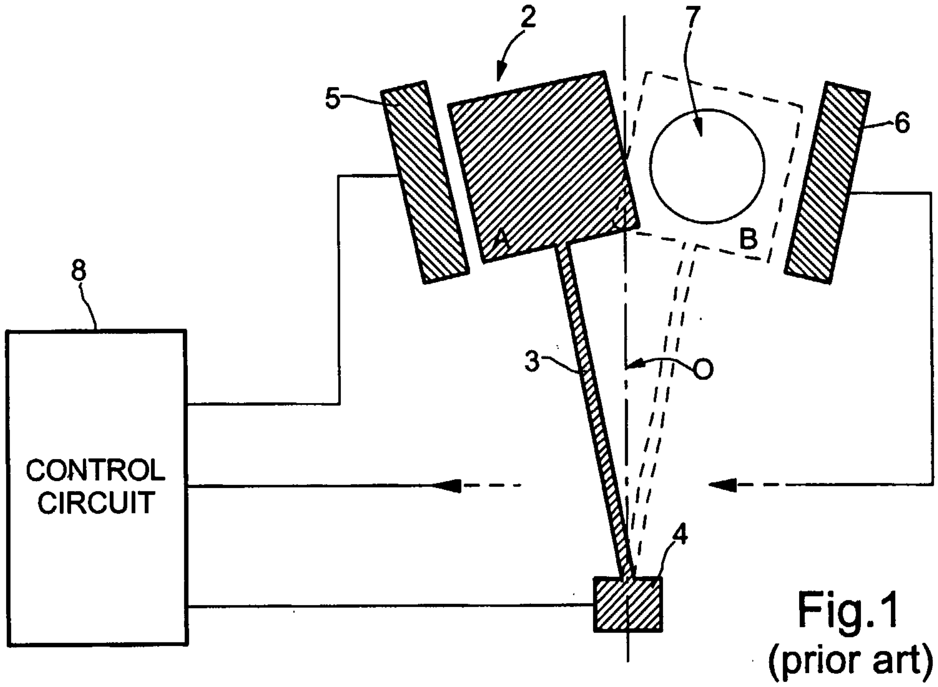


Fig.1
(prior art)

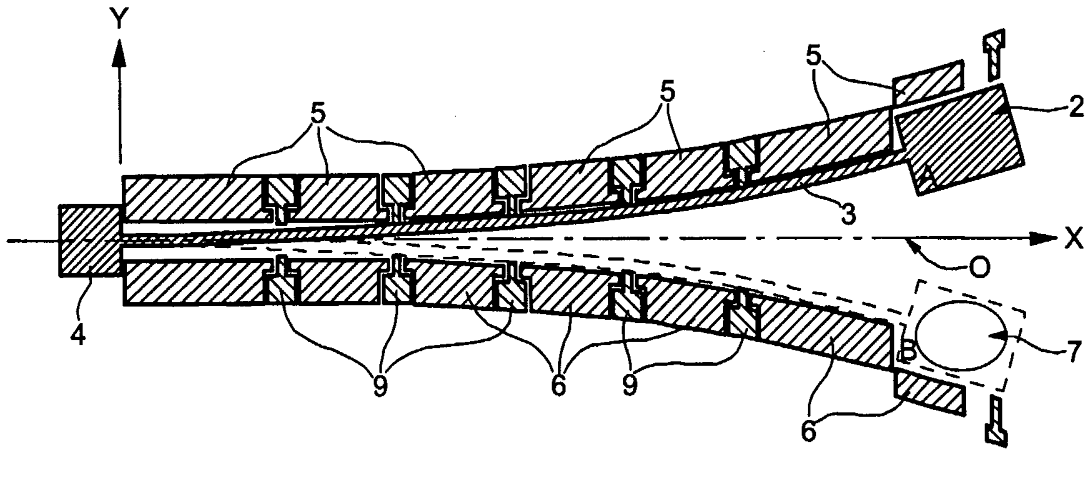
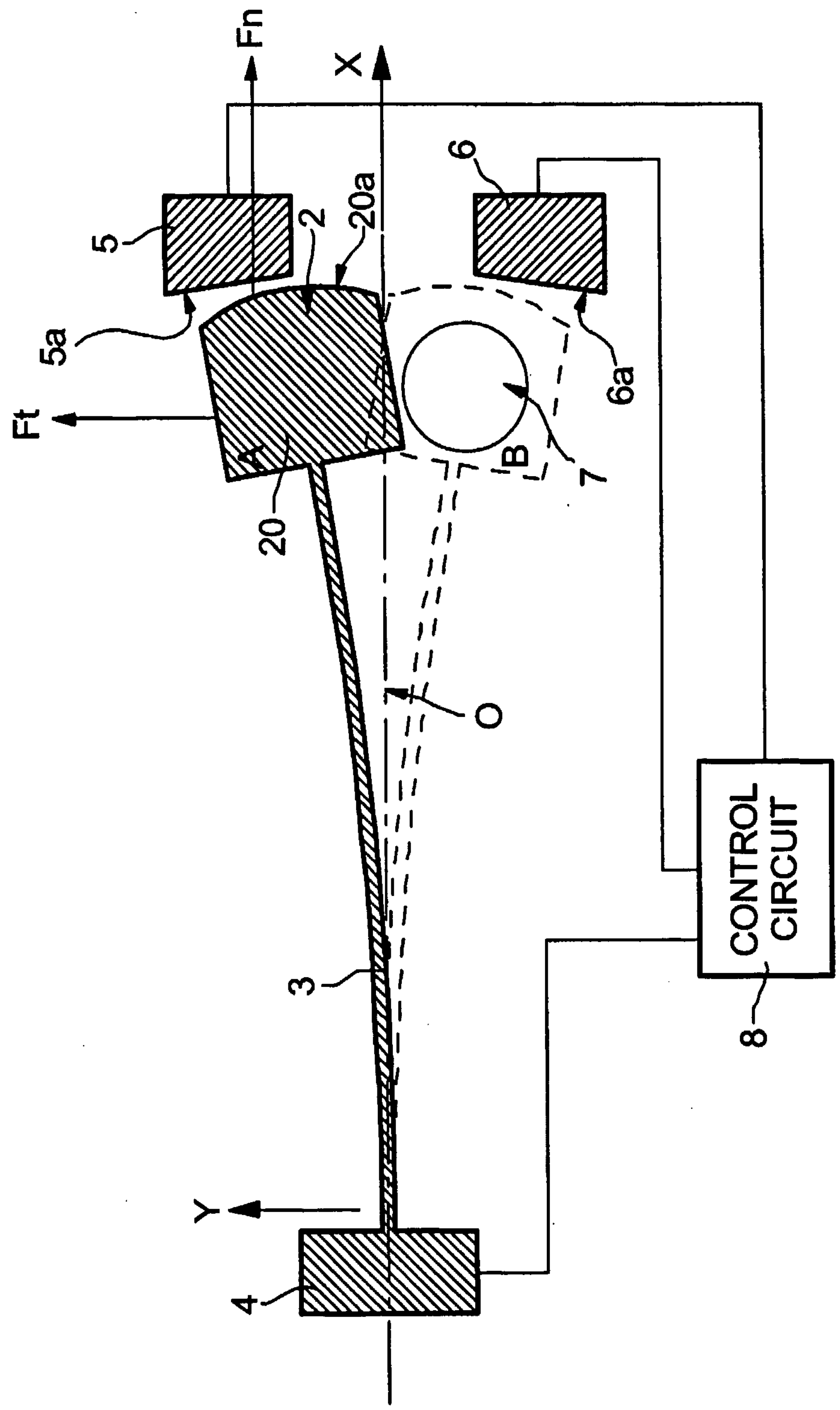


Fig.2
(prior art)

Fig.3



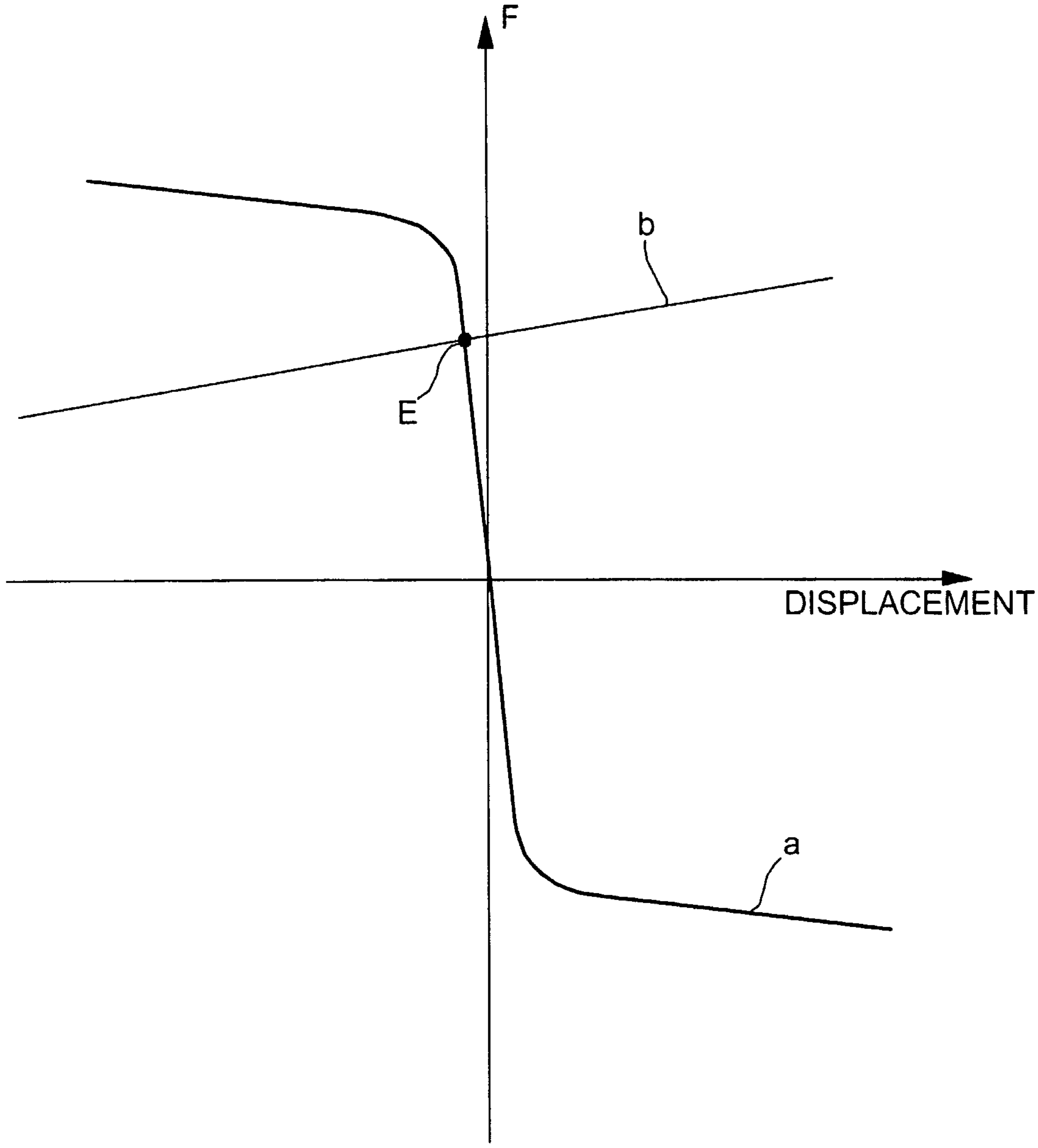


Fig.4

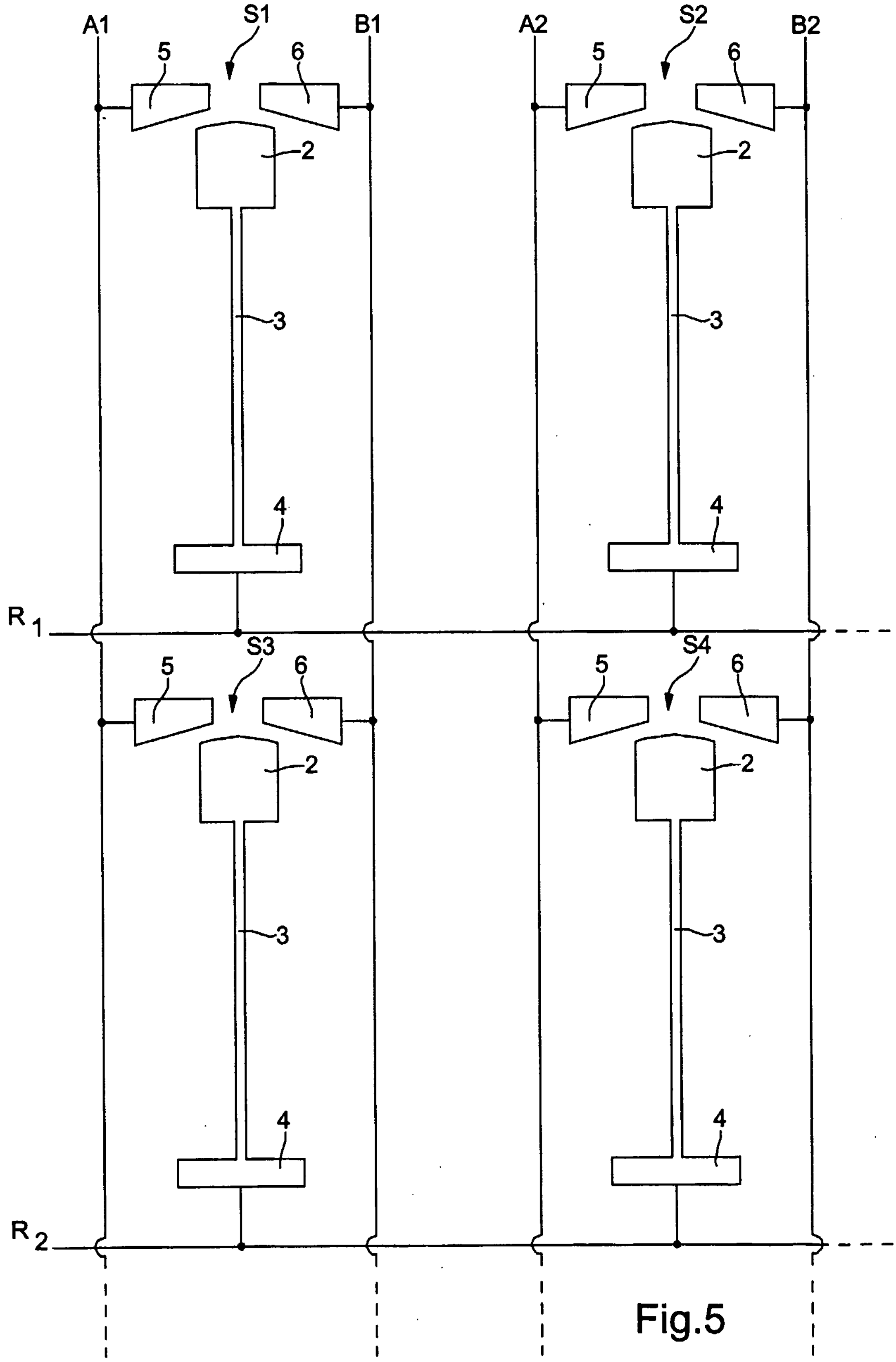
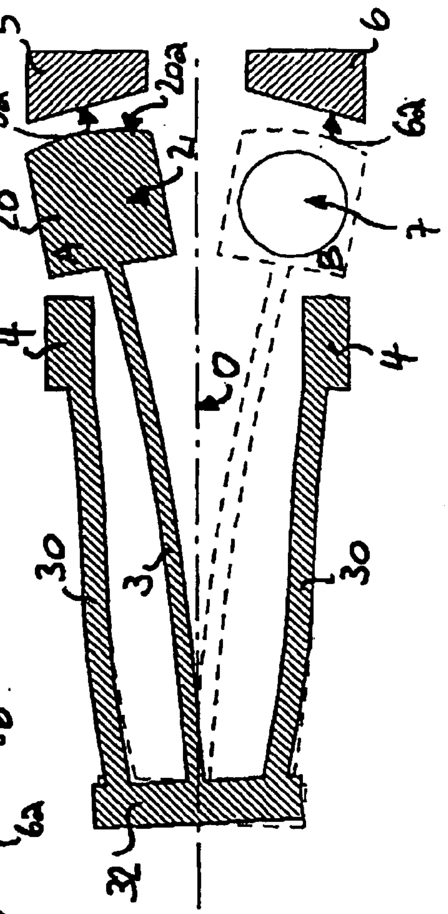


Fig.5

Fig. 6a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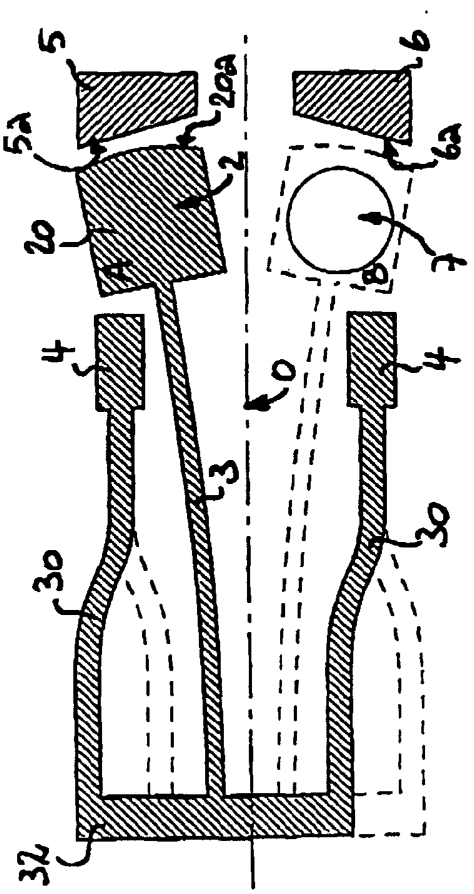
5a
20a
6
6a
20
21
7
A
B
4
4
0
3
30
30
32

Fig. 6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A
B
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3
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30
32

Fig.7

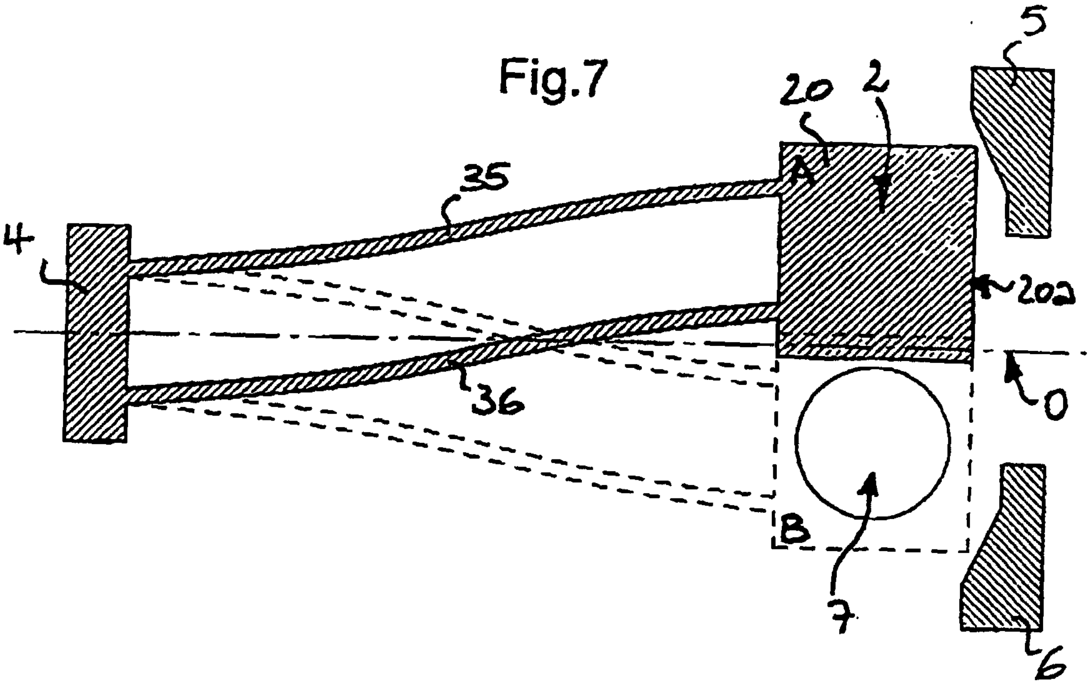
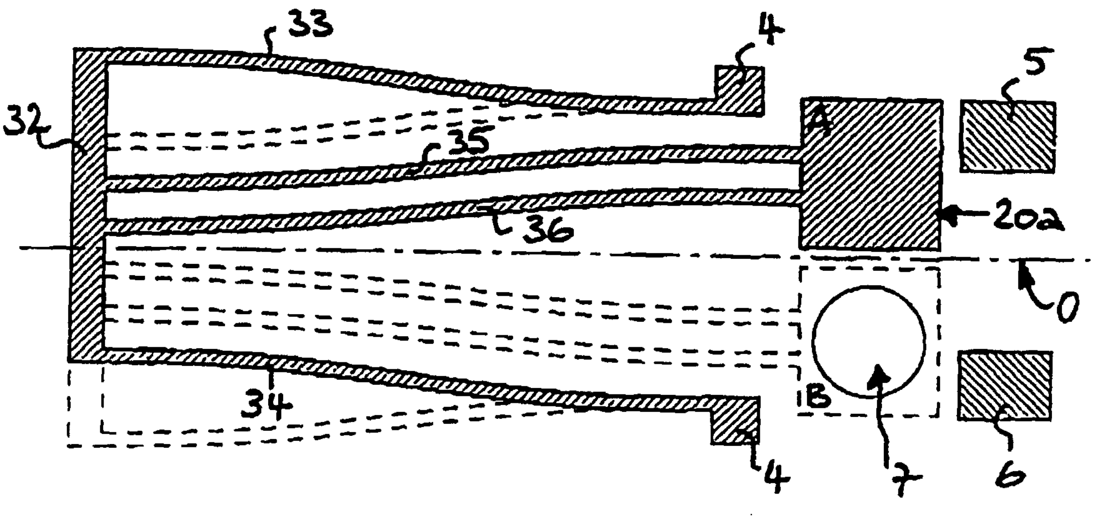


Fig.8



7/8

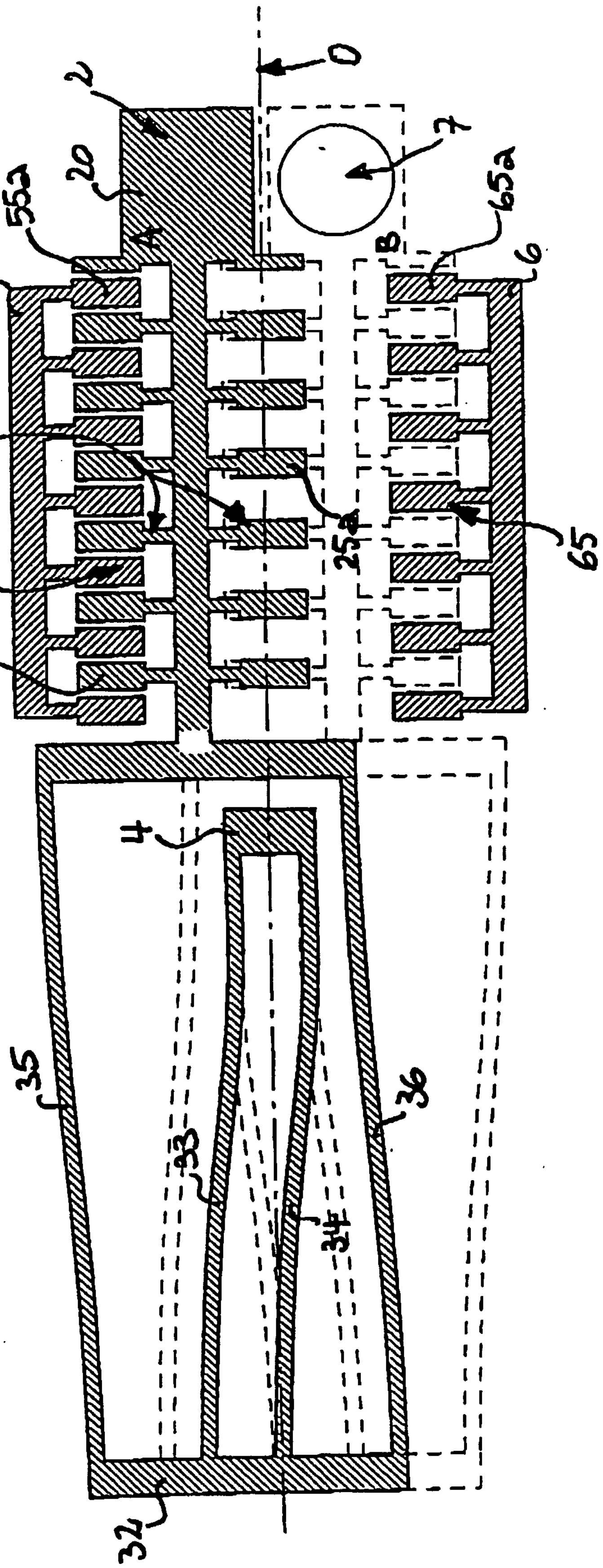


Fig. 9

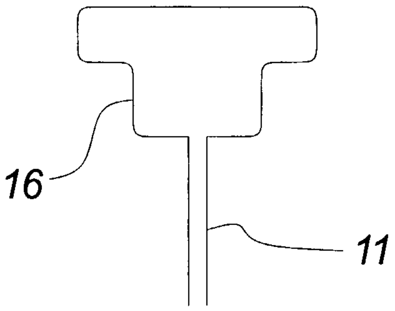


Fig. 10a

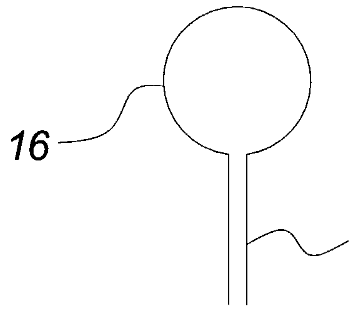


Fig. 10b

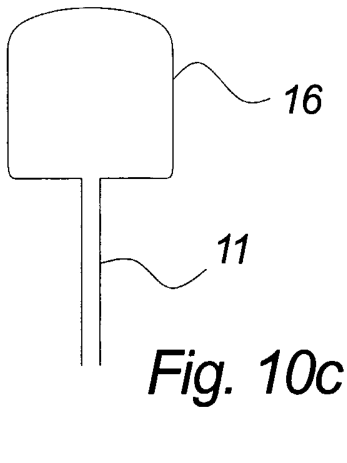


Fig. 10c

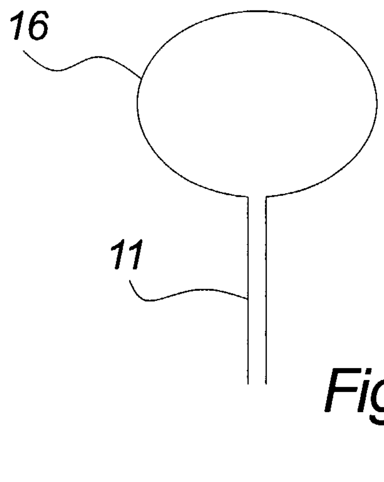


Fig. 10d