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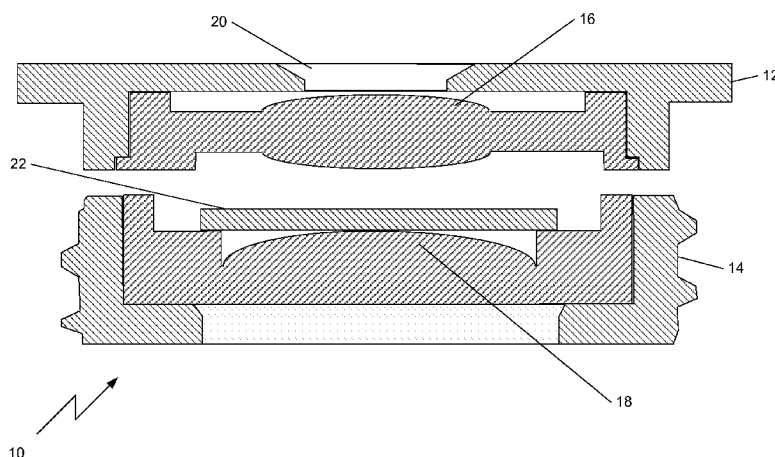


FIGURE 1

(57) Abstract: An electrically controllable optical lens apparatus makes use of fixed lenses and an active optical element together in a lens enclosure. The enclosure may be a barrel structure that is easily mounted to a camera device having an image sensor. The active optical element, such as a tunable liquid crystal lens, receives an electrical signal from the camera device via electrical conductors integral with the lens enclosure that provide electrical pathways between the active element on the interior of the enclosure and surface contacts on the camera device. The enclosure may be a two-piece structure, and the electrical conductors may be attached to either piece of the structure. The lens enclosure may also be threaded for attachment to the camera device. The electrical conductors may also use spring loaded contact portions or molded interconnect devices.



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## OPTICAL LENS HAVING FIXED LENSES AND EMBEDDED ACTIVE OPTICS

This application claims priority of US provisional patent application 61/175,025 filed May 3, 2009.

### FIELD OF THE INVENTION

**[0001]** This invention relates generally to optical devices and assemblies and, more specifically, to lenses having active optical control.

### BACKGROUND OF THE INVENTION

**[0002]** Lens structures for optical devices such as cameras consist of multiple lens elements assembled in a single barrel or stacked in a wafer form, utilizing spacers, to create fixed focus lens assemblies. These lens structures have a fixed focal plane and are mechanically moved to focus on objects in varying distances to the camera system.

**[0003]** Tunable liquid crystal lenses (TLCL) that have a flat layer construction are known in the art, as described in PCT patent application WO 2007/098602, published on September 7, 2007, as well as in PCT patent application WO 2009/153764 published December 23, 2009, the specifications of which are hereby incorporated by reference as if fully set forth herein.

### SUMMARY OF THE INVENTION

**[0004]** In accordance with the present invention, an electrically controllable optical lens apparatus is provided that has a first optical lens and a second optical lens fixed in position relative to each other such that an optical signal can pass through both lenses. Located at a fixed position within the apparatus, which in a first embodiment is a position between the first and second lenses, is an electrically controllable active optical element. The active optical element which may be, for example, a tunable liquid crystal lens (TLCL), changes its optical characteristics from a first state to a second state in response to an input electrical signal, such that it exerts a different optical

influence on the optical signal in the first state than in the second state. In the case of a tunable lens, the active optical element may change between many states, changing the overall optical power of the entire lens apparatus.

**[0005]** In one exemplary embodiment, the lens apparatus has the active optical element positioned within a lens stack. In this configuration, by applying a required electrical signal to the active element, the optical properties of the lens assembly are modified without any mechanical movement. In case of a TLCL as the active optical element, the focal plane of the lens structure could be moved, thus creating a variable focus (*e.g.* auto focus) device. Alternatively, the active element can function as an aperture stop, shutter, IR cut filter or other mechanism in the lens stack, resulting in a possibly shorter and improved overall lens design.

**[0006]** When the TLCL is located inside the stack, the aperture of the TLCL can be smaller than if the TLCL is located outside the stack (typically 25% smaller).

**[0007]** In one embodiment, a lens mounting structure having a barrel shape is used to enable easy assembly of the active element into the lens stack. In this embodiment, a lens barrel is split into two sections at the active optical element plane. Mechanical features on the fixed focus lens elements are used to establish assembly spacing and alignment. In this configuration, the active optical element is designed to be integrated into the stack without interfering with precise alignment and spacing of other optical elements within the stack. A special feature on the fixed elements is used to align and space these elements without interference from the active optical element. The active optical element may have a substantially planar shape and, in one embodiment, is roughly square. With such a square shape, extra space around the active optical element may be used to provide alignment and spacing, which is required in conventional fixed lens systems to achieve acceptable optical performance.

**[0008]** An integrated electrical connection structure and method is also provided to enable electrical contacts as part of the lens barrel assembly. At least one electrical contact provides an electrically conductive path between

an outer surface of the lens mounting structure and the active optical element. The contact may be a stamped metallic piece with an incorporated spring element to ensure reliable electrical connection to a contact on a receiving device to which the lens apparatus is mounted. Alternatively, a molded interconnect device (MID) also may be used to create a connection between the active optical element and camera housing or surrounding devices. An MID would be used in place of lead frames in the device. Connection to the embedded active optical element may be achieved by means of conductive adhesives.

**[0009]** Two different barrel assembly methods and structures are proposed. The first is a threaded barrel with appropriate matching threads on the housing of a receiving device to which the lens apparatus is mounted. In a second variation, a ramp design is used to ensure proper positioning of the contacts with respect to corresponding contacts on the camera housing. In this approach a single thread is created with a locking stop mechanism to define the distance of lens barrel from the sensor in a deterministic way. In the ramp design no focusing operation is required at assembly and optical device relies solely on the active optical element for proper focusing.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0010]** The following figures show features and different embodiment of the proposed design.

Figure 1 is a cross sectional view of a first embodiment of a lens structure according to the present invention

Figure 2 is a perspective view of the lens structure of Figure 1.

Figure 2A is an isolated view of an outer portion of the lens structure of Figure 1 showing an active optical element adjacent thereto.

Figure 3 is a perspective view of a lens structure according to the present invention that uses a ramp structure and electrical connections near a top of a barrel portion of the lens structure.

Figure 4 is a perspective view of a lens structure according to the present invention that uses electrical connections on an inner surface of an inner portion of the lens structure.

Figure 5 is a cross sectional view of a lens structure according to the present invention in which fixed lenses are formed on the surfaces the upper and lower substrates of an active optical element.

Figure 6 is a perspective view of a lens structure according to the present invention in which a molded interconnect device is used to provide electrical connection between an active optical element and an inner surface of an outer portion of the lens structure.

Figure 6A is a perspective view of an interior of an outer portion of the structure of Figure 6 showing the location of electrical contact points.

Figure 6B is a top view of an interior of the lens structure of Figure 6 showing an active optical element in place adjacent to the electrical contact points of the lens structure.

Figure 7 is a perspective view of a lens structure according to the present invention in which a molded interconnect device is used to provide electrical connection between an active optical element and an inner surface of an inner portion of the lens structure.

Figure 7A is a perspective view of an interior of an inner portion of the lens structure of Figure 7 showing the location of electrical contact points.

Figure 8 is a perspective view of a lens structure according to the present invention showing gaps via which an electrically conductive adhesive may be applied to the connection points between an active optical element and the electrical contacts of the lens structure.

Figure 9 is a perspective view of a single barrel configuration in which the present invention may be used, the figure depicting a socket flange base in an exploded view showing the image sensor, circuit board and the various optical elements.

Figure 10A is a top view of an assembly including a unitary image sensor and barrel lens mounting that has a tunable liquid crystal device to provide a tunable focus camera.

Figure 10B is a cross sectional side view of the assembly of Figure 10A.

Figure 11A is a top view of an assembly including a unitary image sensor, a barrel lens mounting and a tunable liquid crystal device, and that functions as a fixed focus camera.

Figure 11B is a cross sectional side view of the assembly of Figure 11A.

Figure 12A is a top view of an assembly similar to that of Figures 11A and 11B, but that has the tunable liquid crystal device located between two lens elements of the structure.

Figure 12B is a cross sectional side view of Figure 12A.

Figure 13A is a cross sectional view of a unitary image sensor and barrel lens mounting that has a top cavity for receiving the tunable liquid crystal lens device after assembly of the image sensor and barrel lens.

Figure 13B is a perspective view of the assembly of Figure 13A with a top cover of the assembly removed.

#### DETAILED DESCRIPTION

**[0011]** The present invention is directed to an optical lens apparatus that uses fixed lenses in combination with an electrically controllable liquid crystal optical device. Depending on the specific configuration, the apparatus may be directed to one of several applications. In each of these embodiments, the apparatus has an overall “barrel structure” and uses the optical properties of the fixed lenses in combination with the electrically controlled optical properties of the liquid crystal device.

**[0012]** Shown in Figure 1 is a schematic view of a first embodiment of the invention in which a variable focus lens 10 has a barrel structure consisting of two portions, an outer portion 12 and an inner portion 14. The lens may be used in a variety of different applications, including compact digital cameras, such as might be integrated into a portable telephone. Each of the two portions includes a fixed lens, lens 16 in the outer portion 12, and lens 18 in the inner portion 14. Light from a subject in front of the outer portion 12 is collected via aperture 20 and focused by the outer portion fixed lens 16. This focused light is refocused by the fixed lens 18 of the inner

portion to form an image on a desired imaging device, such as a CMOS or a charge-coupled device type detector, etc. (not shown). The overall focusing of the variable focus lens 10 is, however, adjustable by way of a tunable lens 22 positioned between the fixed lens 16 and the fixed lens 18.

**[0013]** In the present embodiment, the tunable lens 22 is a tunable liquid crystal lens (TLCL), such as that discussed in PCT patent application publication WO 2009/153764 published December 23, 2009, the substance of which is incorporated herein by reference. As is discussed in this and other disclosures, a TLCL is a liquid crystal based lens structure for which the focusing power changes with changes to an applied electric field. As the electric field is typically generated by an input electrical signal, variation of that signal may be used to change the tuning of the lens. The tuning range of the TLCL may include a zero optical power level at which it adds no focusing effect to the overall lens structure. However, as the electrical signal supplied to the TLCL changes, the optical power of the lens changes with it, causing an overall change in the focal length of the variable focus lens 10.

**[0014]** The two portions of the variable focus lens 10 are shown separated from each other in Figure 1, but are part of a single integral component during operation. In the present embodiment, the two portions are separate and are joined together at the position of the active optical plane, i.e., the location of the TLCL. When assembled, the variable focus lens has a “barrel” shape, as is evident in the perspective view of Figure 2. In the present embodiment, the barrel shape has a thread 24 along its curved outer surface, allowing the variable lens to be screwed into a threaded hole on an apparatus (such as a camera) on which it is installed, although other connection means may be used instead.

**[0015]** Also shown in Figure 2 are a set of electrical contacts 26 by which electrical connection with the TLCL may be made. These contacts can be stamped metallic pieces with incorporated spring elements that help ensure reliable electrical connection. Corresponding electrical contacts on the apparatus to which the lens is mounted allow convenient electrical signal routing. The relative positioning of the TLCL 22, which in this embodiment

has a generally square shape, and the outer portion 12 of the barrel structure is shown in the isolated view of Figure 2A. This figure provides a view of the interior of the barrel structure, and shows how electrical contacts located in the corners of the TLCL 22 make contact with the electrical contacts 26 of the barrel structure. Thus, electrical continuity is easily provided from a surface of the apparatus to which the lens is mounted to the electrically-activated TLCL 22 on the interior of the lens structure.

**[0016]** An alternative arrangement for assembly of the system uses a ramp or cam surface 28 on the barrel of the lens 10, as is shown in Figure 3. This ramp allows for barrel adjustment during assembly. The ramp is essentially a circumferential lip that extends radially from an outer surface of the barrel, and that includes a flat surface 29 that functions as a stop mechanism during rotation of the barrel. When the barrel is inserted into a mounting socket of a device to which the barrel is attached, the ramp 28 makes contact with a corresponding ramp on an inner surface of the mounting socket (not shown). As the barrel is rotated counter-clockwise (relative to a view facing an outer surface of outer portion 12), the two ramps slide against each other until the flat surface 29 of the ramp 28 meets a corresponding flat surface of the mounting socket. Thus, when the barrel is attached to the housing of the corresponding optical device using the ramp method, the barrel stops in a predetermined position with respect to an internal component of the device, such as a CMOS sensor. The barrel may then be permanently attached to the device using, for example, adhesive or ultrasonic welding, or any other technique known in the art. Using this arrangement, no focusing operation is required at assembly, and the optical variable lens 10 relies solely on the TLCL for proper focusing. Those skilled in the art will recognize that other ways of providing assembly may also be used.

**[0017]** Another embodiment of the present invention is shown in Figure 4, and makes use of electrical contacts located at the innermost surface of the barrel structure. This is in contrast to the positioning of the contacts on an inner surface of the outer portion 12, as shown, for example, in Figure 2. In both embodiments, the electrical contacts 26 pass between the outer portion



12 and the inner portion 14 to make contact with the TLCL. However, while the contacts of the Figure 4 embodiment extend to a surface of the inner portion 14, where they will make contact with corresponding contacts of the apparatus to which the variable lens is mounted 10, those of the Figure 2 embodiment are extended to the aforementioned inner surface of the outer portion. The particular configuration of the contacts in one of these two arrangements is a matter of design convenience.

**[0018]** In still another embodiment of the invention, a fixed lens integral with the TLCL is used. As shown in Figure 5, the TLCL includes a fixed lens 30 molded onto its surface. Further disclosure of such a lens construction set out in PCT patent application publication WO/2010/022503 published March 4, 2010, the specification of which is hereby incorporated by reference.

**[0019]** Figure 6 shows another variation of the present invention in which a molded interconnect device (MID) approach is used to create a connection between the active optical element and the camera housing or surrounding devices. This embodiment is similar to that shown in Figure 2, but in place of stamped metal contact pieces, MID elements 32 are used. As with the contacts of the Figure 2 embodiment, The MID elements pass in between the inner portion 14 and the outer portion 12 of the barrel and make electrical connection to the embedded active optical element by way of conductive adhesives. In this embodiment, the MID elements may form contact surfaces 34 on an interior of the outer portion 12 of the barrel, as is shown in Figure 6A. These contact surfaces 34 allow for an easy means of making an electrical connection to the active optical element such as a TLCL 22. Figure 6B, for example, is a view of the outer portion 12 with a TLCL 22 having the corners of its square shape positioned adjacent to the contact surfaces 34. Surface electrical contacts located in the corners of the TLCL 22 thereby make electrical contact with the contact surfaces 34 of the outer portion. When the outer portion 12 is assembled with the inner portion 14 of the barrel, the corners of the TLCL 22 rest between surfaces of the two portions, and may be thereby held in place in the barrel.

**[0020]** As with the stamped metal contact embodiment, the MID contacts may also extend to an inner surface of the inner portion 14. In the embodiment shown in Figure 7, the MID contacts 36 are positioned to make contact with corresponding contacts on a surface of the device to which the lens structure is attached. The MID contacts 36 in this embodiment extend along an interior surface of the inner portion 14 to locations adjacent to the active optical element. This is shown more clearly in Figure 7A, which is an isolated view of the inner portion 12 of Figure 7 as seen from the opposite side. While the active optical element (such as a TLCL 22) is not shown in this figure, those skilled in the art will understand that such an element with a square shape could rest within the barrel with corresponding electrical contacts located in the corners of the square shape located adjacent to the interior surfaces of the MID contacts 36.

**[0021]** In each of the embodiments having an active optical element within the barrel making contact with electrical contacts located substantially between an inner portion and an outer portion of a barrel structure, the two portions may be constructed such that, when assembled together, small gaps remain between them in the vicinity of the electrical contacts. Such gaps 38 are shown in the perspective view of Figure 8, although it will be understood by those skilled in the art that such gaps may be used with any of the embodiments described herein. Since the electrical contacts of the active optical element will reside adjacent to the electrical contacts of the barrel assembly, gaps 38 may serve as access points by which to apply a conductive adhesive that both secures the electrical components together and provides a more robust electrical connection between them.

**[0022]** It will be appreciated that the barrel can be provided with a base, for example incorporating a flange, and that electrical connections between the active embedded optical element and the circuit board may be through the barrel base. The barrel body incorporates the required conductors to conduct signals from the circuit board to the contacts on the barrel body in contact with the active element. Figure 9 illustrates a conventional single barrel having a socket flange base in an exploded view showing the image sensor 40, circuit

board 42 and the various optical elements, including fixed lenses 44, IR glass 46 and TLCL 47, which is protected by barrel cover 48. The base contacts and integration of the conductors and embedded active optical element contacts are not detailed in Figure 9. An arrangement such as shown in this figure may be used with the present invention. In such a case, the barrel body shown in Figure 9 would be one of those presented in the foregoing embodiments, with the active optical element positioned therewithin between the two barrel portions.

**[0023]** The present invention also includes the possibility of using active optical devices other than lenses in a configuration such as that presented herein. For example, in an arrangement similar to that shown in Figure 1, in place of TLCL 22, an electrically activated shutter may be provided.

**[0024]** In the embodiment of Figures 10A and 10B, there is shown a design for incorporation of a barrel with an active optical element (in this case a TLCL) into a camera module unit. Figure 10A is a top view of the device, and indicates the section line corresponding to the cross-sectional view of Figure 10B. As shown, the barrel (i.e., lens/TLCL assembly) 50 fits within housing assembly 52, which is mounted to PC board substrate 54, which also supports image sensor 56. It is beneficial in this, and other, embodiments that the two fixed lens components make contact with each other to ensure a proper alignment and orientation between them. In this embodiment, the housing is threaded to receive the threaded barrel assembly, and includes four metallic inserts 58, such as lead frames, for completing connection from the barrel assembly 50 to the camera substrate. Since the barrel assembly 50 includes conductive contacts 51 that are electrically connected to the active optical element 53, the metallic inserts 58 provide the necessary electrical pathways to the substrate. Thus, this configuration allows electrical connection between the active optical element 53 and the substrate 54, despite the fact that the barrel assembly may have imprecise height and rotational angle relative to the housing.

**[0025]** As indicated in the inset portion of the drawing, the metallic inserts 58 are electrically connected to the board 54 using conductive glue 60, although solder could also be used. The housing 52 itself is also connected to the substrate 54 using glue (typically non-conductive), but bumps 62 are provided on the bottom of the housing surface which extend beyond the glue to make contact with the substrate 54. In this way, a precise distance is maintained between the housing 52 and the substrate 54 which is not affected by the thickness or flatness of the glue layer.

**[0026]** In the embodiment of Figures 11A and 11B, there is shown a fixed focus camera module. Figure 11A is a top view of the device, and shows a section line along which the cross section of Figure 11B is taken. Two lens elements 64 are permanently mounted within a housing 66 with no adjustability for focus. A TLCL 68 is located at the side of the housing opposite PC board substrate 70, to which is mounted image sensor 72. As in the embodiment of Figures 10A and 10B, electrical connection is made between the substrate and the TLCL via metallic inserts 74 that run vertically in the corners of the housing, being connected to the substrate via conductive glue 76. In the same manner as the embodiment of Figures 10A and 10B, the housing 66 also makes use of bumps at its base to provide a precise setoff between the housing and the substrate 70. A top cover 78 of the housing blocks light except that in the main optical path, and provides mechanical protection to TLCL 68, which is mounted at the top of the device, above the fixed lenses.

**[0027]** Normally, most miniature cameras consist of a separate housing and a lens barrel, among other parts. One important operation during construction is to thread the lens barrel into the housing, activate the sensor, and adjust the focus by turning the barrel to achieve the best focus for camera system. This operation requires special equipment and is costly due to extra operation and reducing yield by creating particles due to rubbing of barrel surface against the housing thread surface.

**[0028]** A focus-free camera module refers to a camera module that is constructed by utilizing a camera housing with lenses integrated into the

housing permanently before attachment to the sensor substrate. Thus, for a configuration such as that shown in Figures 11A and 11B, there will be no adjustment of focus during the assembly process. The main issue with such a construction is that the tolerances of the assembly (physical and optical) may not be tight enough to ensure a precise focus at the sensor surface, and an out-of-focus image may result. However, in the present embodiment, minute focus errors may be compensated for by adjusting the optical power of the TLCL 68.

**[0029]** In the embodiment of Figures 12A-12B, a focus-free camera module uses an active optical element (TLCL 80) is located between primary lens 82 and secondary lens 84 of the lens stack. This configuration is similar to that of Figure 11, except for the location of the TLCL. A focus plane of the lens structure can be actively adjusted by changing the optical power of the TLCL 80 to compensate for an improper distance of the lens stack from the sensor 85. As with the embodiment of Figures 11A and 11B, this design enables construction of cheaper cameras, utilizing parts with usual tolerances and without any focusing operation.

**[0030]** The top view of Figure 12A shows the location of metallic inserts 86 along the side edges of the lens housing 88. Unlike the Figure 11A, 11B embodiment, the metallic inserts do not run all the way to the top of the housing but, rather, only to the vertical position of the TLCL 80. This is shown in the cross section of Figure 12B, which is taken along the section line shown in Figure 12A and which shows the relative positions of the fixed lenses and the TLCL within the housing. The inserts 86 are connected to the substrate 87 using conductive glue 90, and the housing has a setoff bump, as in the previous embodiments. This configuration, along with the capability of the embedded TLCL to adjust the focus plane, can enable proper camera focus without adjustment of the barrel.

**[0031]** In the embodiment of Figures 13A-13B, the camera need not be a fixed-focus camera. This design shows an easy and low cost way of incorporating a TLCL 94 into a conventional camera module. In this configuration, a camera housing 96 is designed and molded in such a way

that there is a cavity on the top of the housing to receive the TLCL, while allowing for a barrel-type lens to be inserted into a socket in the housing before inserting the TLCL. Once assembled, the TLCL 94 resides directly adjacent to the lens barrel 98, in close proximity to the lens elements. Connection is provided by metallic inserts 100, as apparent from Figure 13B, which shows the housing with top cover 95 removed. These connectors can also be seen in the cross sectional view of Figure 13A which, like earlier embodiments, is taken along a diagonal section line. This embodiment may also use a conductive glue to connect the metallic inserts to the substrate 102 and the setoff bumps that function as in the previous embodiments.

**[0032]** This camera module can include a conventional lens barrel 98 that is threaded into the housing. One possible assembly sequence for the assembly of this embodiment is to attach the housing, including the lens barrel, to the substrate 102 that supports the CMOS sensor. At this time, the electrical contacts 100 in the housing can be connected to the substrate by the conductive adhesive over the connection pads on the camera substrate. After attachment, the lens barrel 98 is turned and focused, as is done in conventional camera modules, and glue added to the threads to fix the barrel in the desired position. After this camera is tested, the bare TLCL 94 (TLCL part with no housing or FPC) is placed into the top cavity and aligned with respect to the lens barrel aperture. At this time, conductive adhesive is applied to connect the contacts on the TLCL to the electrical contacts in the housing, after which the top cover 95 is placed over the TLCL 94 to close the housing. In an arrangement such as this, therefore, focus tuning of the device can be done manually and by adjustment of the TLCL.

**[0033]** It will be appreciated that in various embodiments, the active optical element can be placed on the top, in the middle, or on the bottom of other lens elements depending on the optical design of the fixed element lenses. In each of these cases electrical connections can be made similarly. It will also be appreciated that, in terms of construction, the lens barrel can be constructed in two pieces or as a single piece.

What is claimed is:

## CLAIMS

1. An electrically controllable optical lens apparatus comprising:
  - a first optical lens through which an optical signal passes;
  - a second optical lens that is fixed in position relative to the first optical lens and through which the optical signal passes; and
  - an electrically controllable active optical element that is located at a fixed position between the first and second lenses and through which the optical signal passes, the active optical element changing its optical characteristics from a first state to a second state in response to an input electrical signal, such that the active optical element exerts a different optical influence on the optical signal in the first state than in the second state.
2. An optical lens apparatus according to Claim 1 wherein the active optical element comprises an electrically tunable lens.
3. An optical lens apparatus according to Claim 2 wherein the active optical element comprises a tunable liquid crystal lens.
4. An optical lens apparatus according to Claim 1, 2 or 3 wherein the first lens is mounted in a first portion of a lens enclosure and the second lens is mounted in a second portion of the lens enclosure, and wherein the first and second portions of the lens enclosure may be rigidly secured to each other.
5. An optical lens apparatus according to Claim 4 wherein the lens enclosure is a barrel structure.



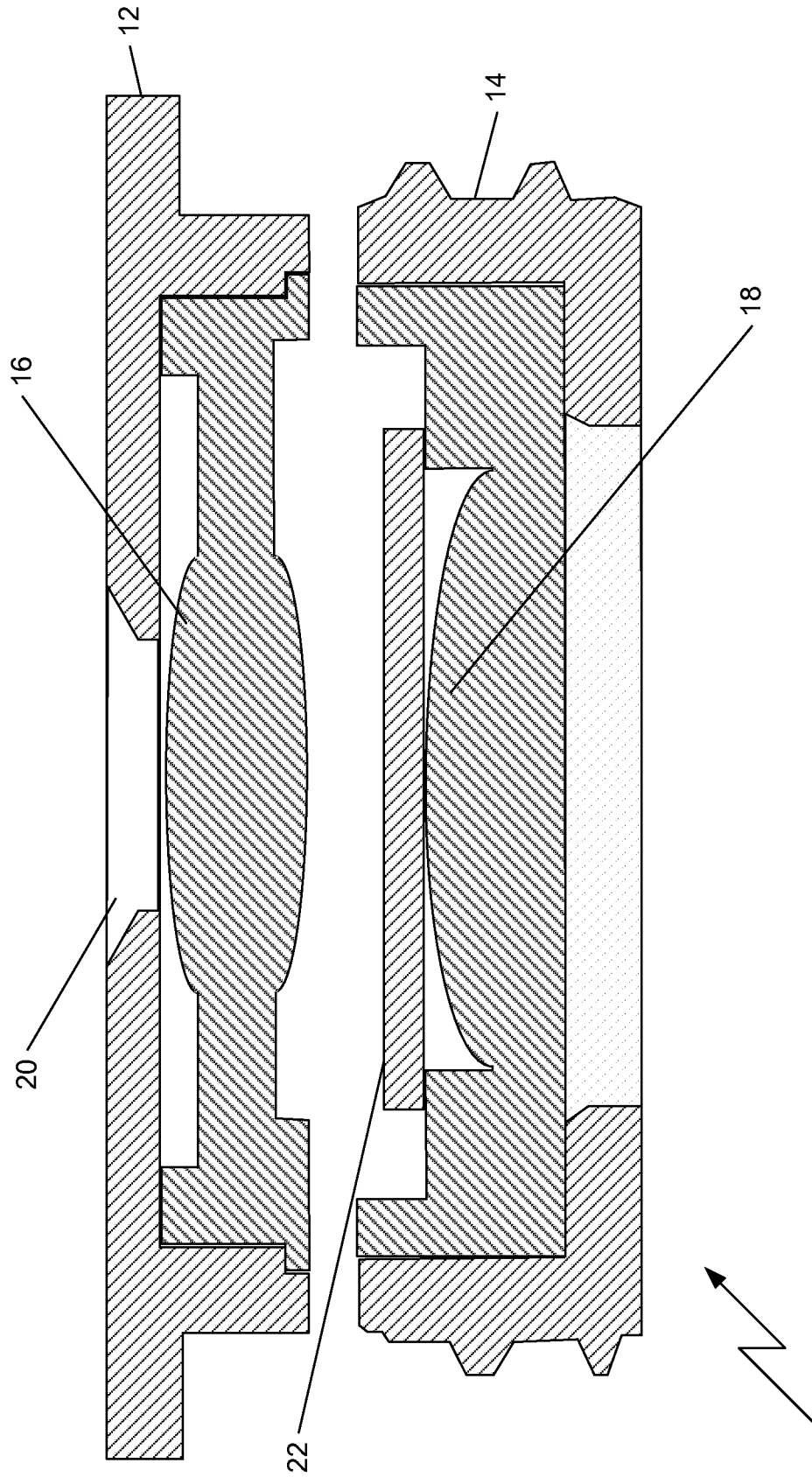
6. An optical lens apparatus according to Claim 4 wherein the active optical element is located between the first and second portions of the lens enclosure.
7. An optical lens apparatus according to Claim 4 further comprising at least one electrical conductor that provides an electrically conductive path between an outer surface of the lens enclosure and the active optical element.
8. An optical lens apparatus according to Claim 7 wherein the electrical conductor comprises a spring biased contact.
9. An optical lens apparatus according to Claim 7 wherein the electrical conductor comprises a molded interconnect device.
10. An optical lens apparatus according to Claim 7 further comprising an electrically conductive adhesive between the electrical conductor and the active optical element.
11. An optical lens apparatus according to Claim 7 wherein the active optical element has a substantially planar shape and a conductive portion of the active optical element adjacent to an edge of the planar shape is in electrical communication with the electrical conductor.
12. An optical lens apparatus according to Claim 4 wherein the lens enclosure comprises a detent by which the lens enclosure may be connected to a receiving device making use of the lens apparatus.
13. An optical lens apparatus according to Claim 12 wherein the detent comprises a screw thread.

14. An optical lens apparatus according to Claim 12 wherein the detent comprises an alignment element that facilitates the location of the lens enclosure in a desired position relative to the receiving device.
  
15. An electrically controllable optical lens apparatus comprising:
  - a first optical lens through which an optical signal passes;
  - a second optical lens that is fixed in position relative to the first optical lens and through which the optical signal passes;
  - an electrically controllable active optical element that is located at a fixed position relative to the first and second lenses and through which the optical signal passes, the active optical element changing its optical characteristics from a first state to a second state in response to an input electrical signal, such that the active optical element exerts a different optical influence on the optical signal in the first state than in the second state;
  - a lens enclosure that encompasses the first and second optical lenses and the active optical element, said enclosure being rigidly mounted to an image sensor housing that contains an image sensor for receiving the optical signal and that has at least one electrical contact on an outer surface; and
  - at least one electrical conductor integral with the lens enclosure that provides an electrical path between the active optical element within the enclosure and an external surface of the enclosure such that, when the enclosure is mounted to the image sensor housing, electrical communication is established between the electrical conductor and a corresponding electrical contact of the image sensor housing.
  
16. An optical lens apparatus according to Claim 15 wherein the first lens is mounted in a first portion of the lens enclosure and the second lens is mounted in a second portion of the lens enclosure, and wherein the

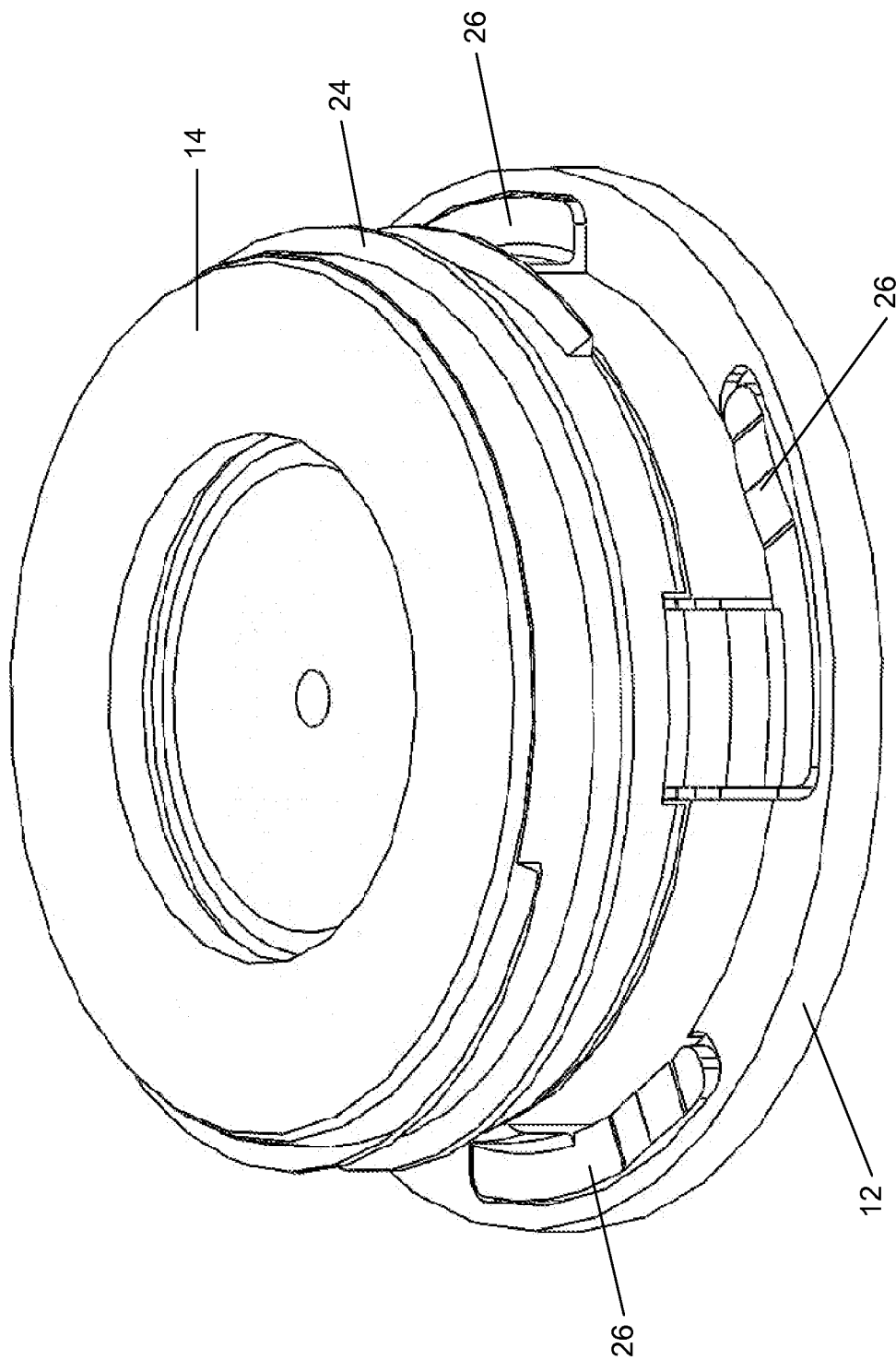
first and second portions of the lens enclosure may be rigidly secured to each other.

17. An optical lens apparatus according to Claim 15 wherein the lens enclosure comprises a barrel structure.
18. An optical lens apparatus according to Claim 15 wherein the active optical element is located between the first and second lenses.
19. An optical lens apparatus according to Claim 15 wherein the electrical conductor comprises a spring biased contact.
20. An optical lens apparatus according to Claim 15 wherein the electrical conductor comprises a molded interconnect device.
21. An optical lens apparatus according to Claim 15 further comprising an electrically conductive adhesive between the electrical conductor and the active optical element.
22. An optical lens apparatus according to Claim 15 wherein the active optical element has a substantially planar shape and a conductive portion of the active optical element adjacent to an edge of the planar shape is in electrical communication with the electrical conductor.
23. An optical lens apparatus according to Claim 15 wherein the lens enclosure comprises a detent by which the lens enclosure may be connected to a receiving device making use of the lens apparatus.
24. An optical lens apparatus according to Claim 23 wherein the detent comprises a screw thread.

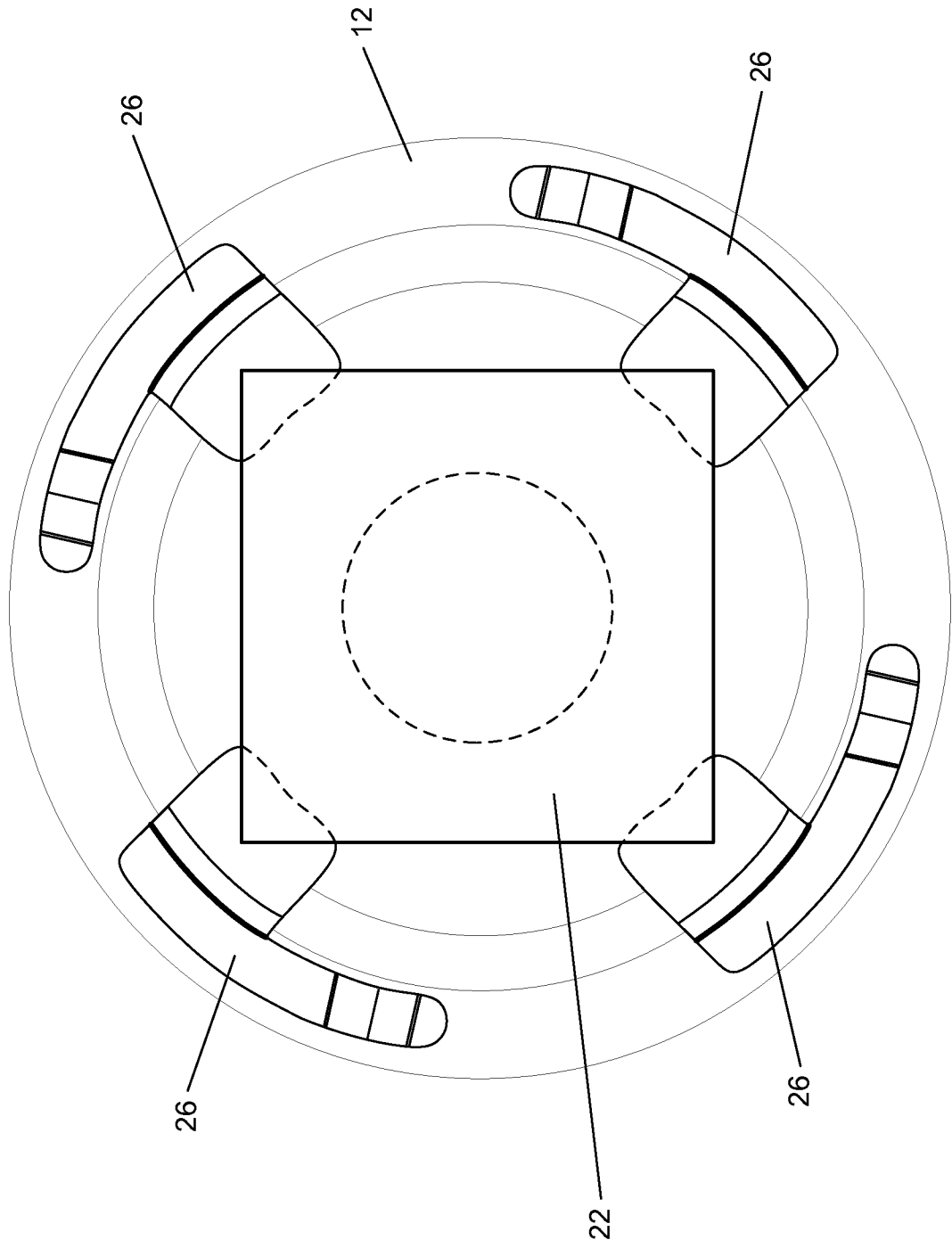
25. An optical lens apparatus according to Claim 23 wherein the detent comprises an alignment element that facilitates the location of the lens enclosure in a desired position relative to the receiving device.
  
26. A camera module comprising:
  - a barrel lens assembly;
  - a tunable liquid crystal lens;
  - an image sensor; and
  - a mounting having a base configured to connect to an image sensor, a socket for adjustably receiving said barrel lens assembly, an adjustment of said barrel lens assembly with respect to said image sensor allowing for an initial focus adjustment, and a top or a bottom mounting for receiving said tunable liquid crystal lens.



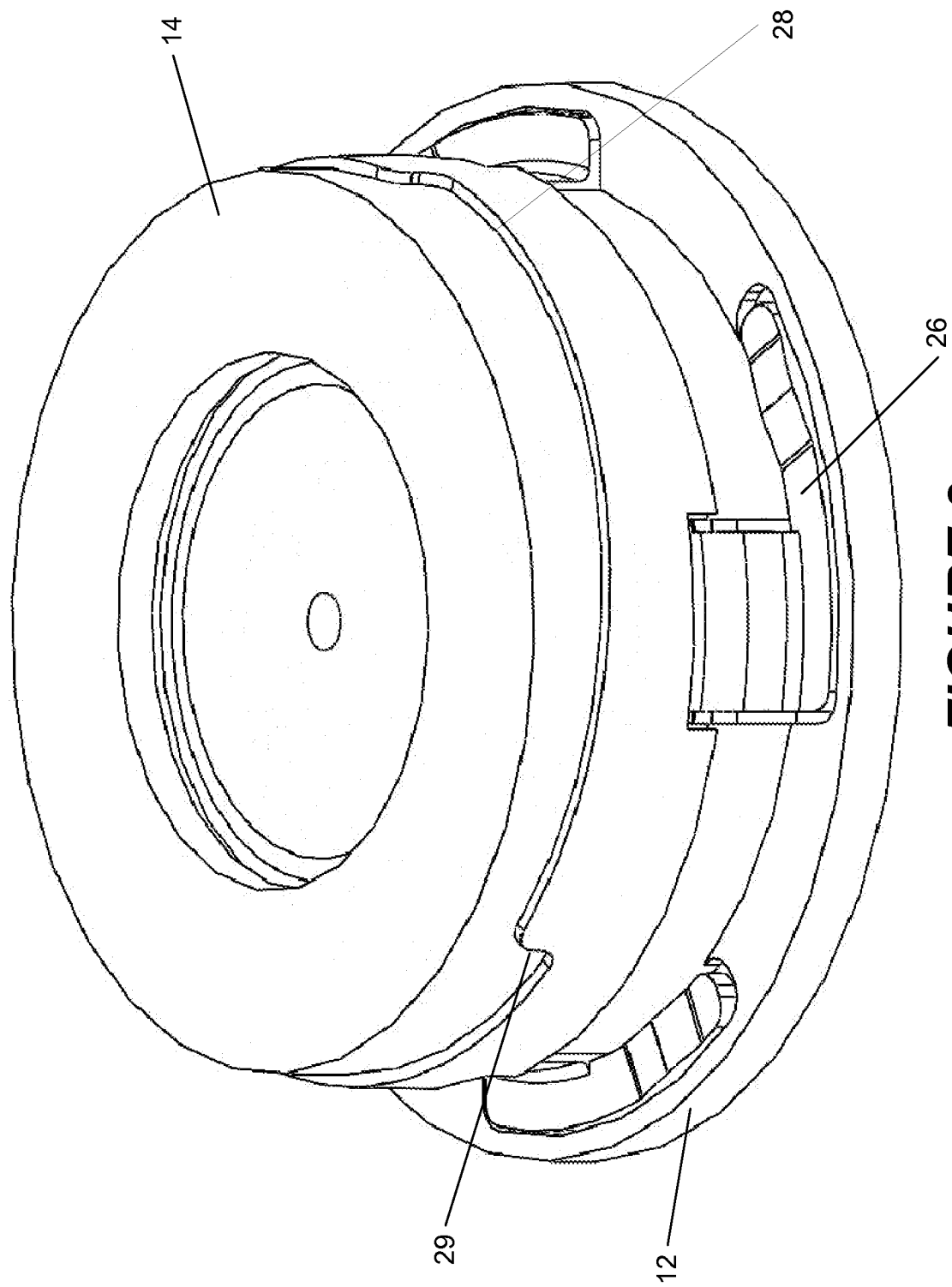
**FIGURE 1**



**FIGURE 2**

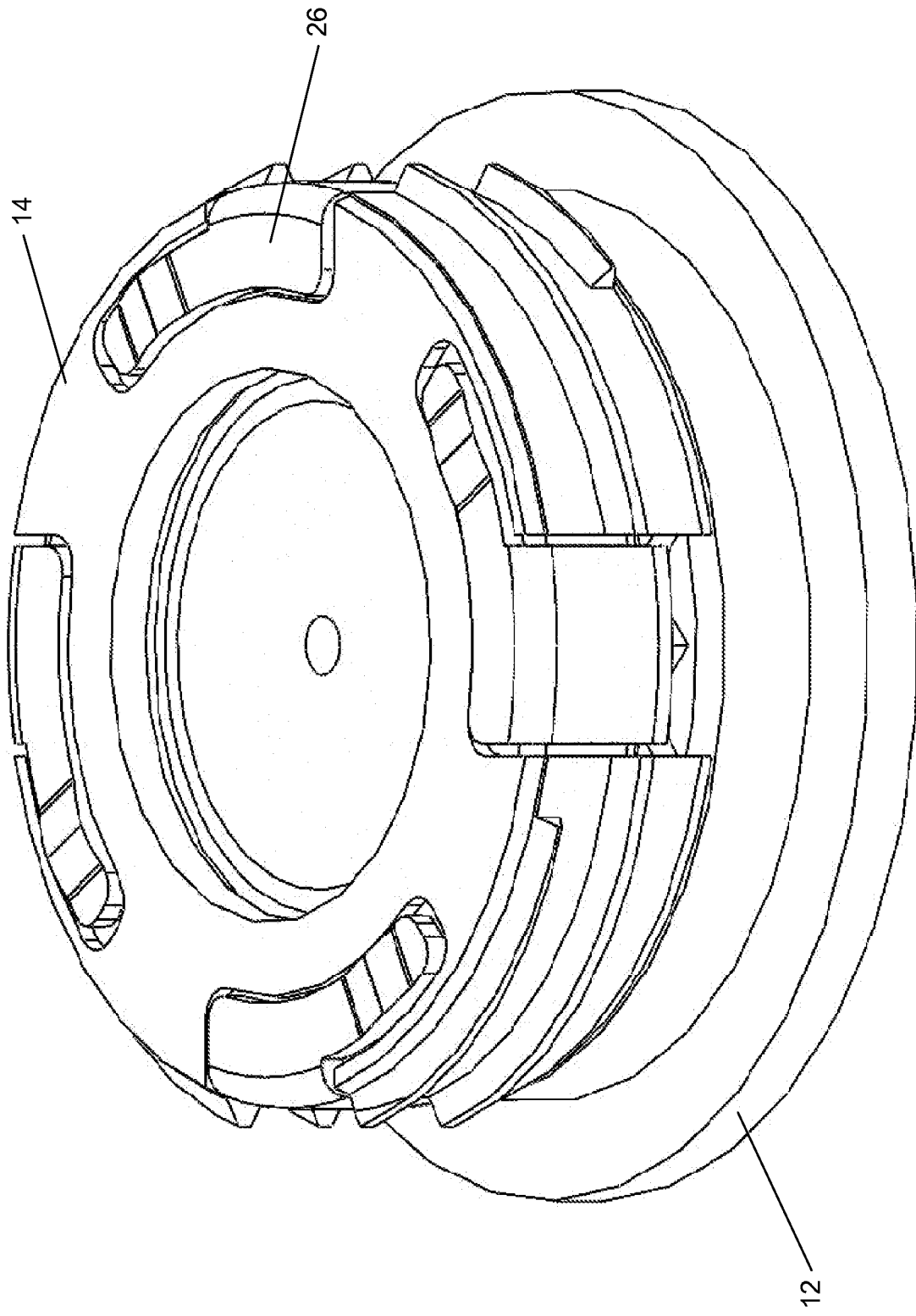


**FIGURE 2A**

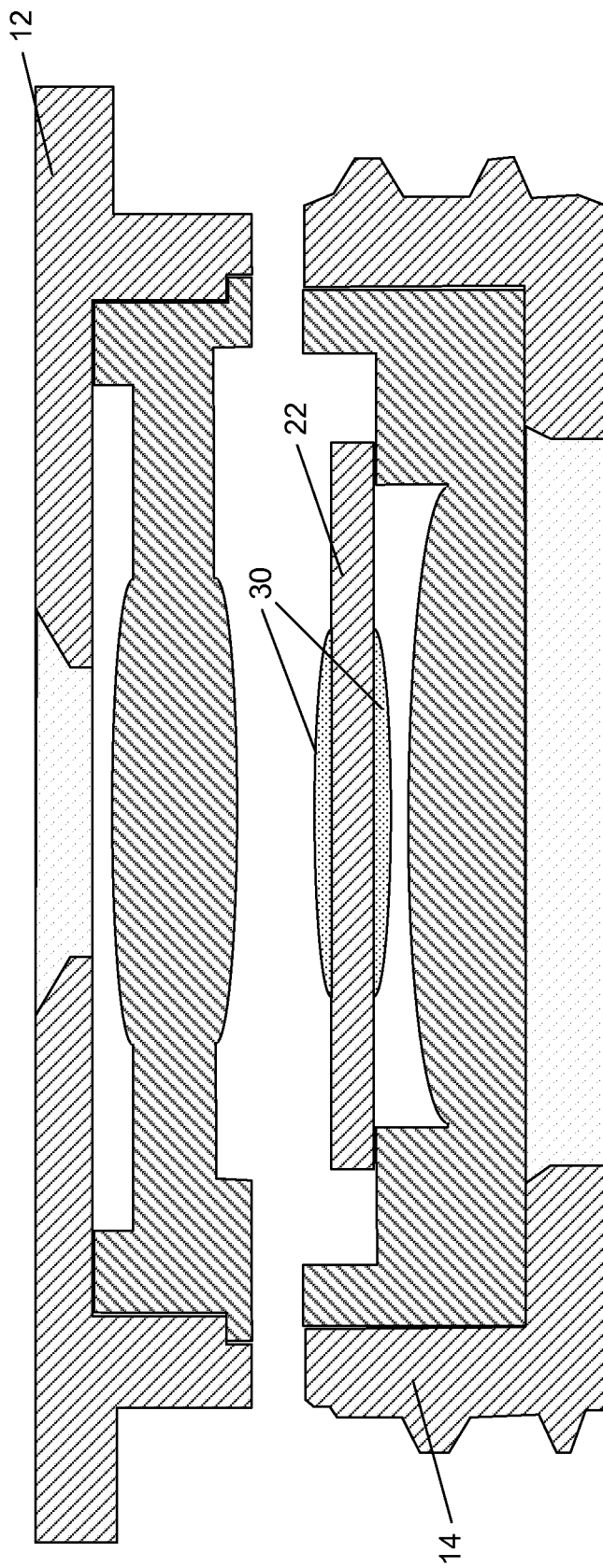


**FIGURE 3**

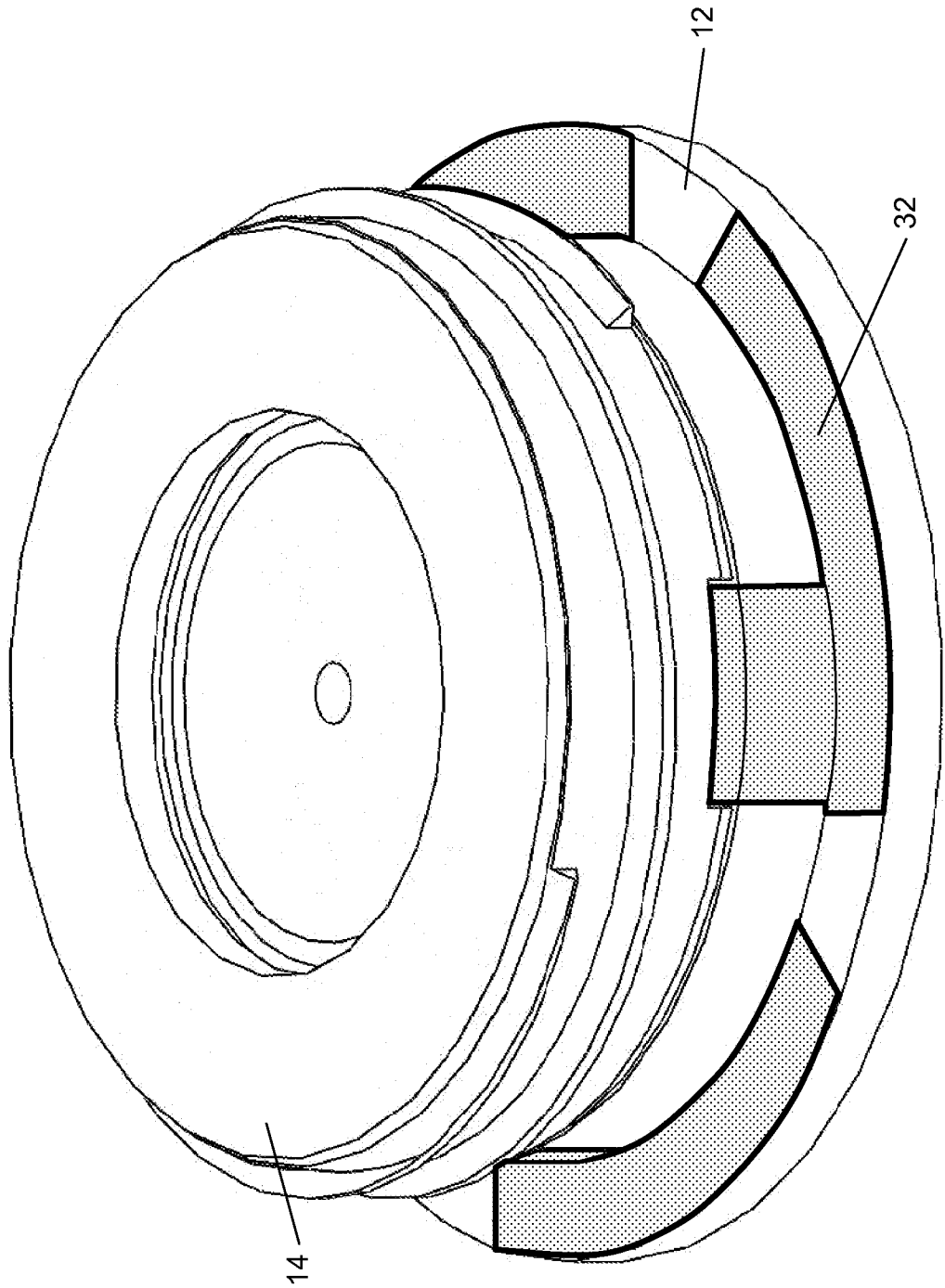




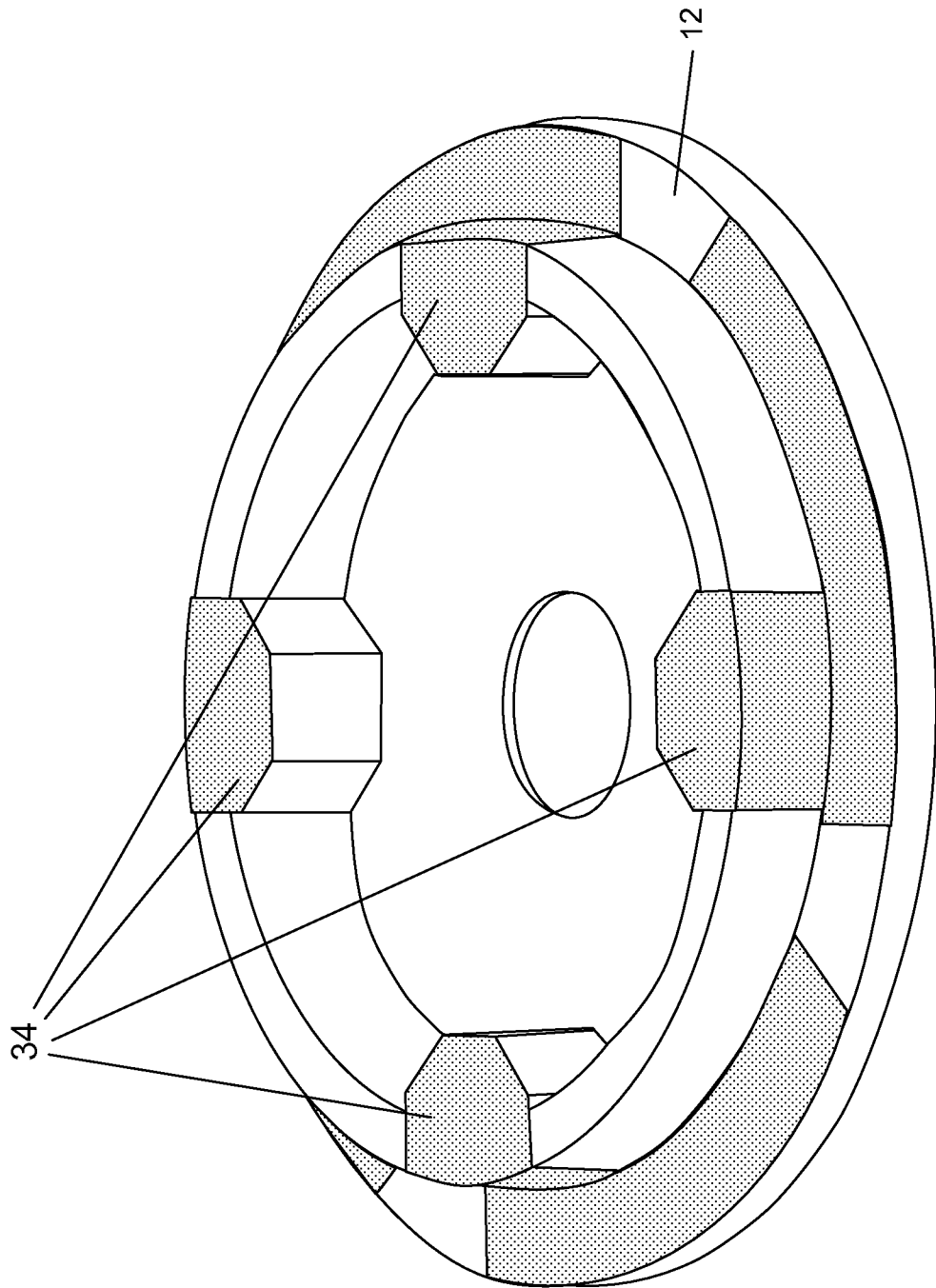
**FIGURE 4**



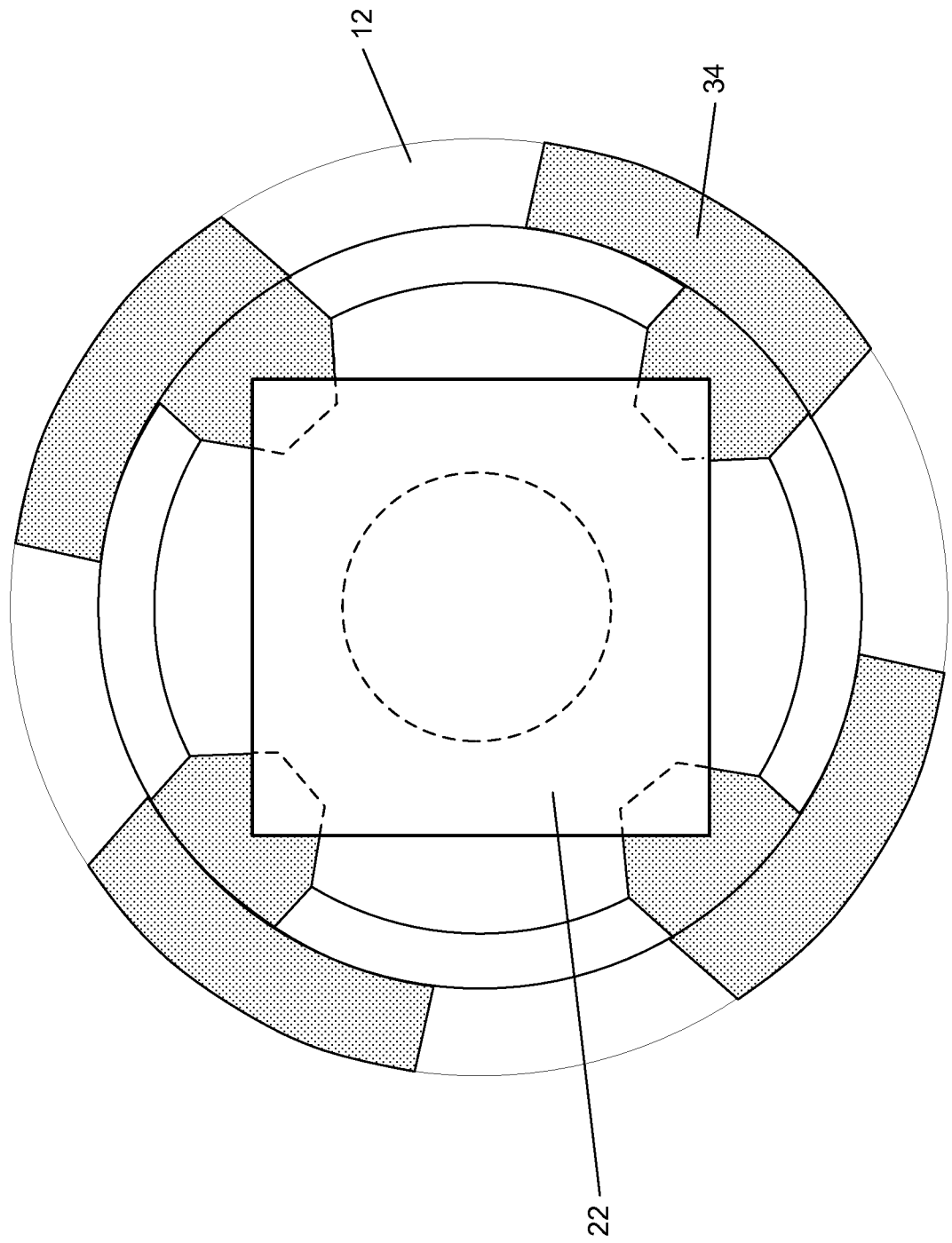
**FIGURE 5**



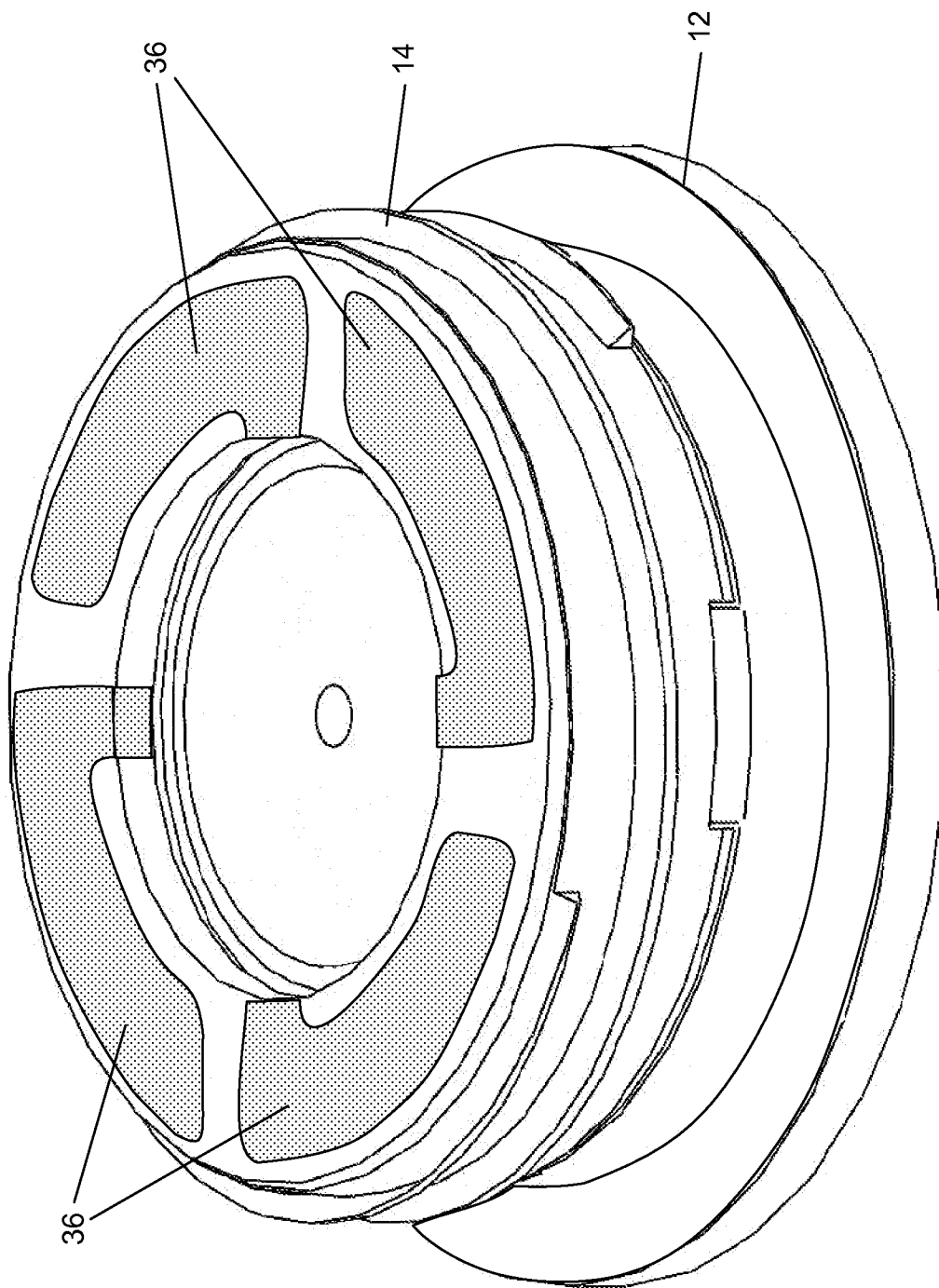
**FIGURE 6**



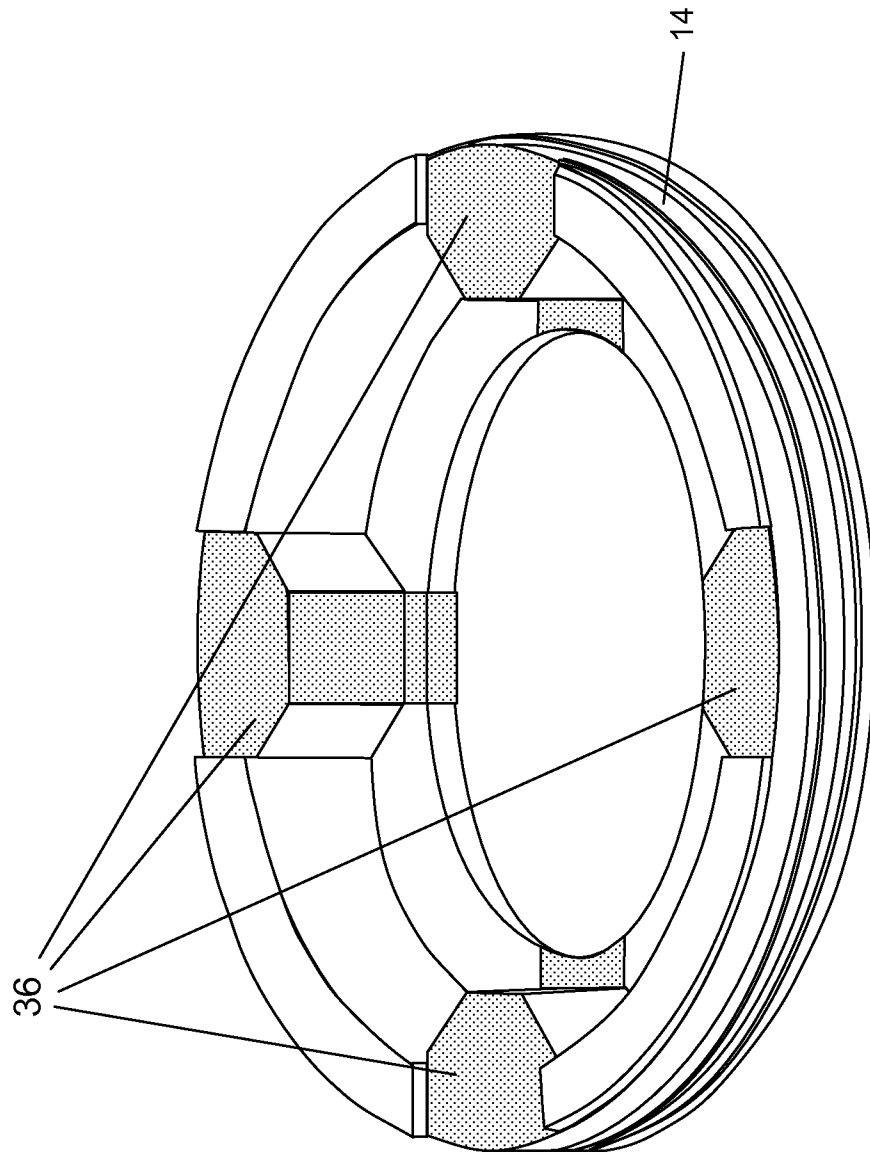
**FIGURE 6A**



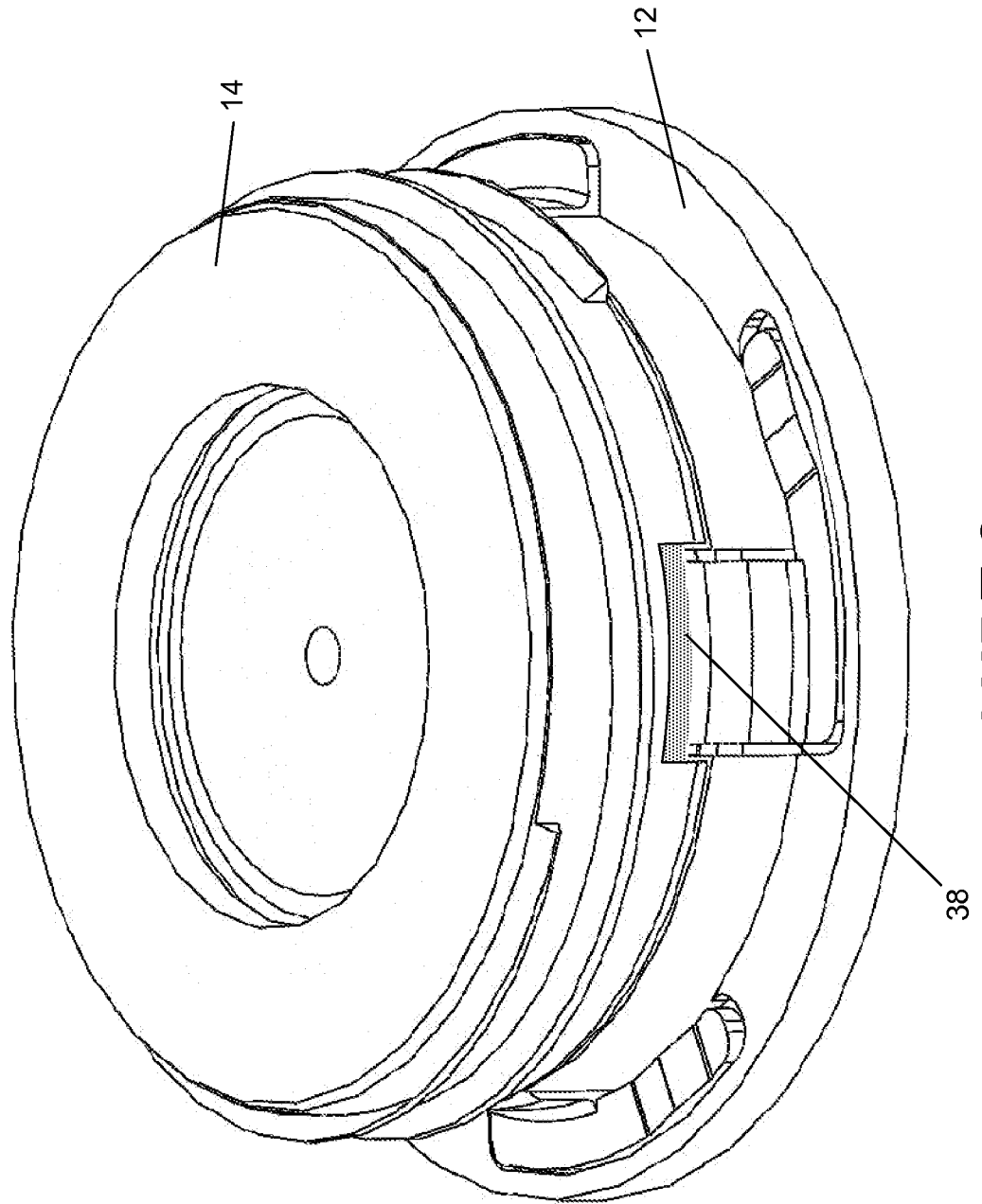
**FIGURE 6B**



**FIGURE 7**

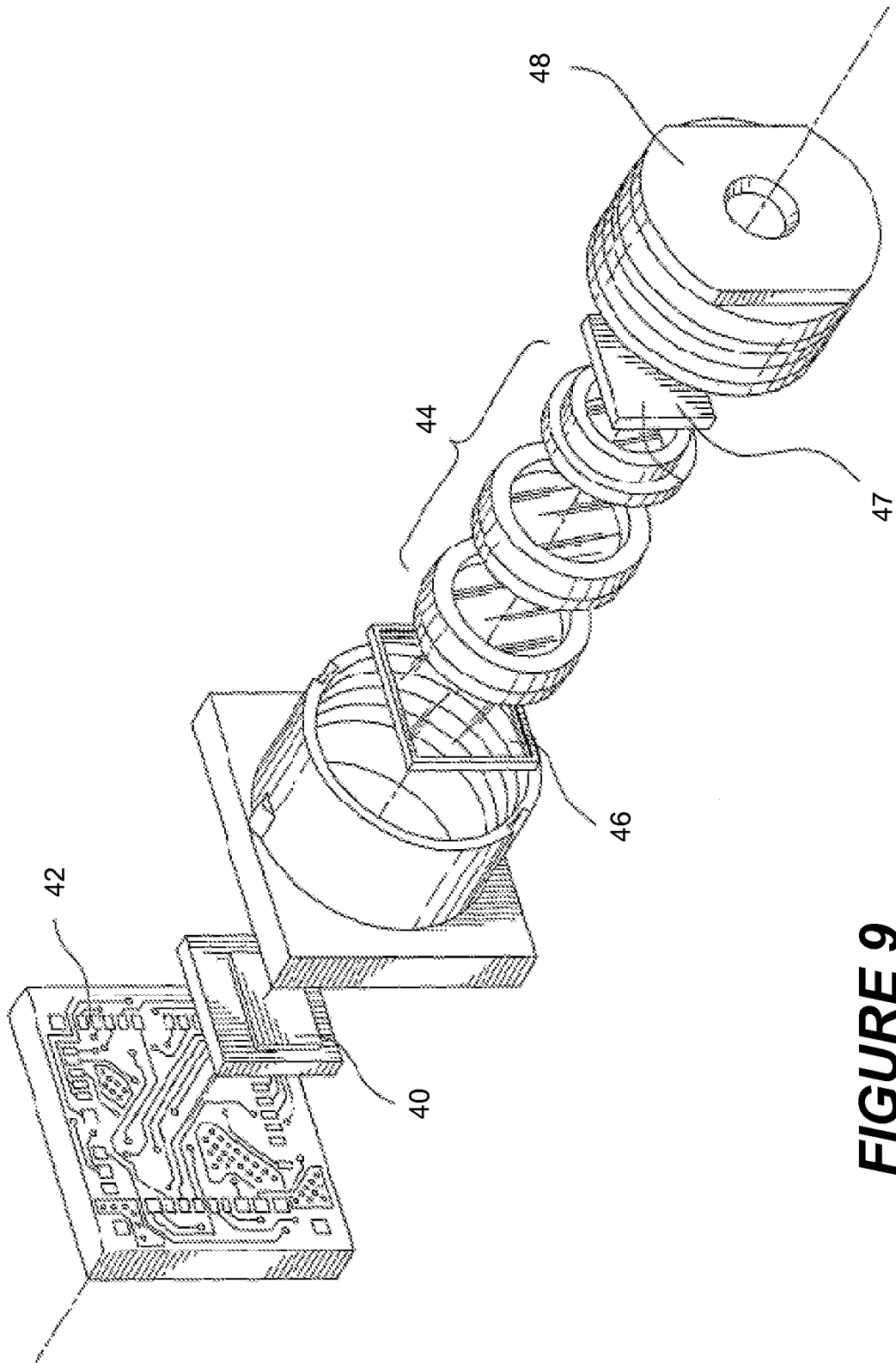


**FIGURE 7A**

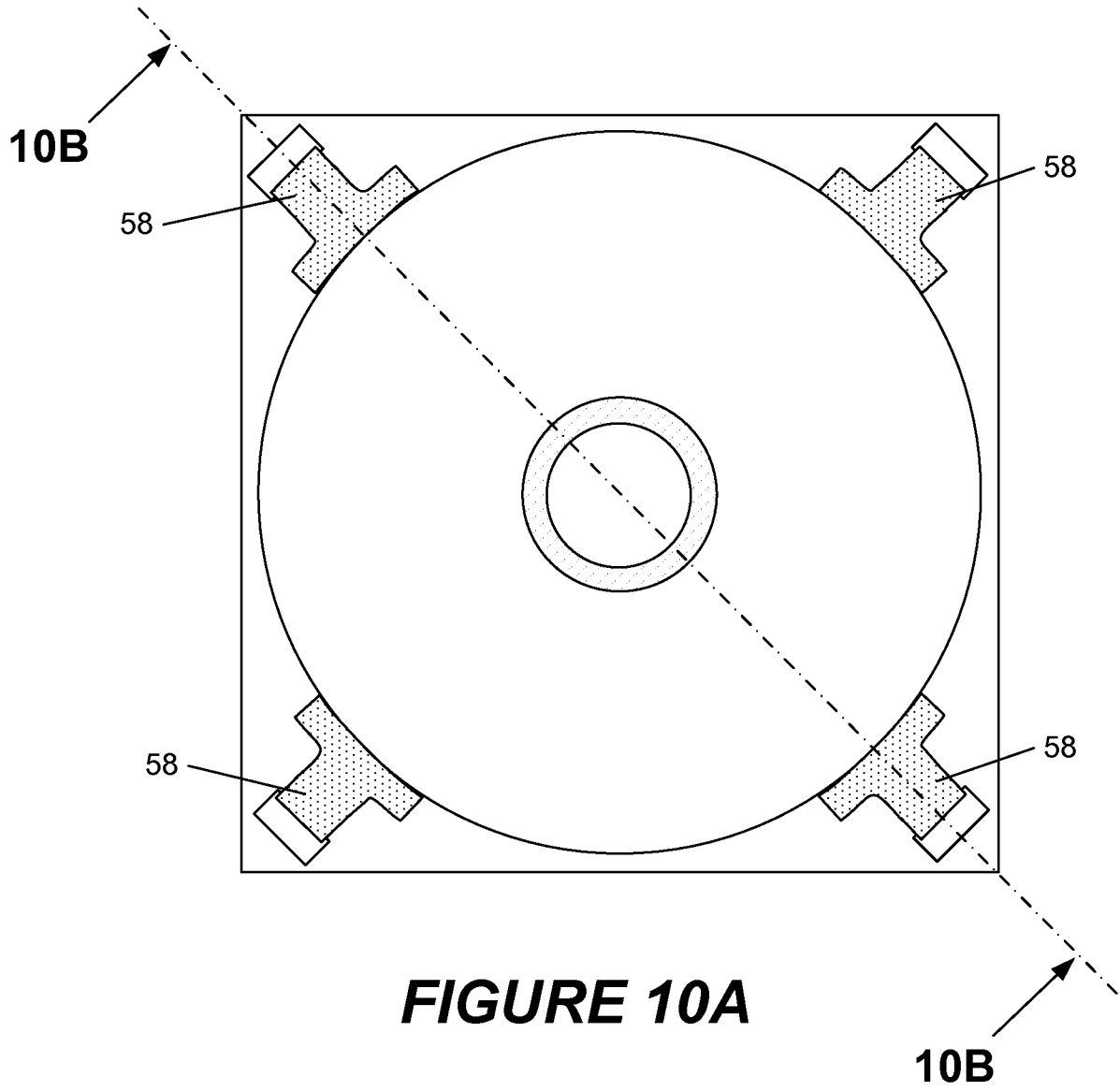


**FIGURE 8**

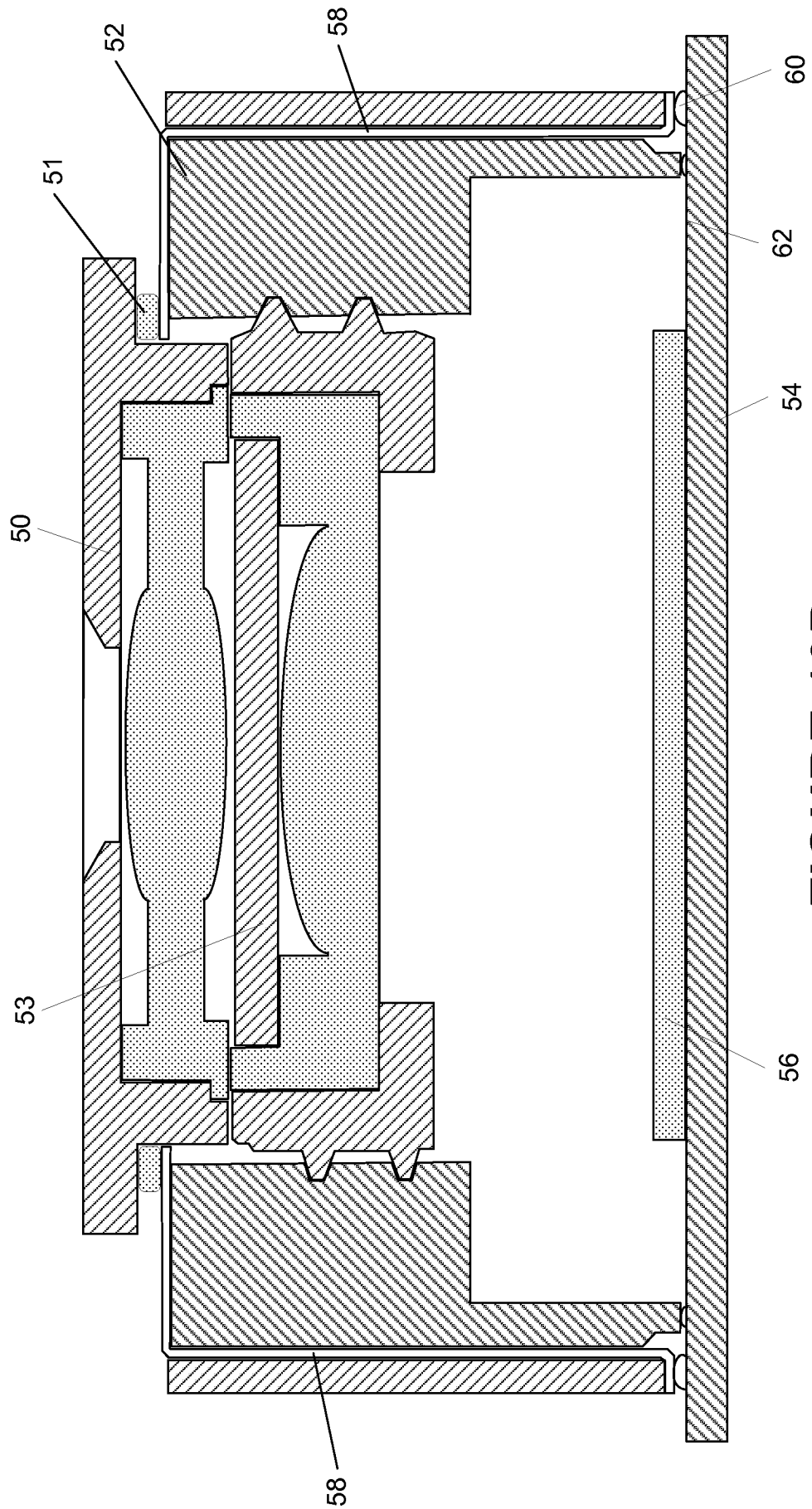




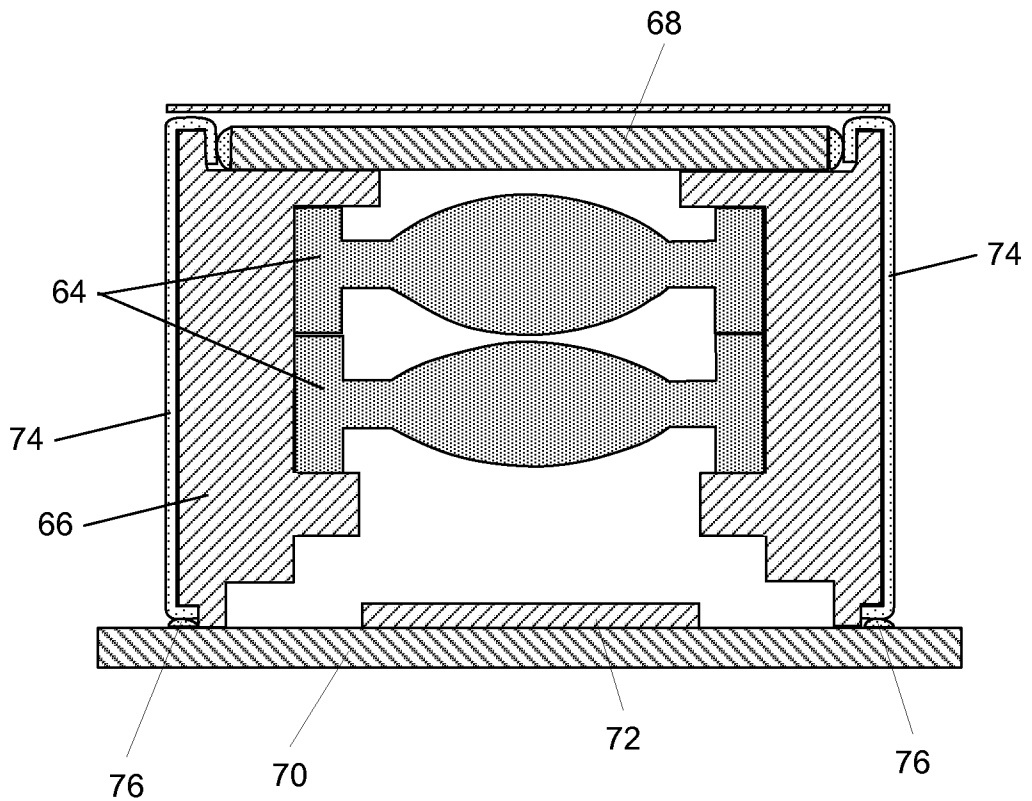
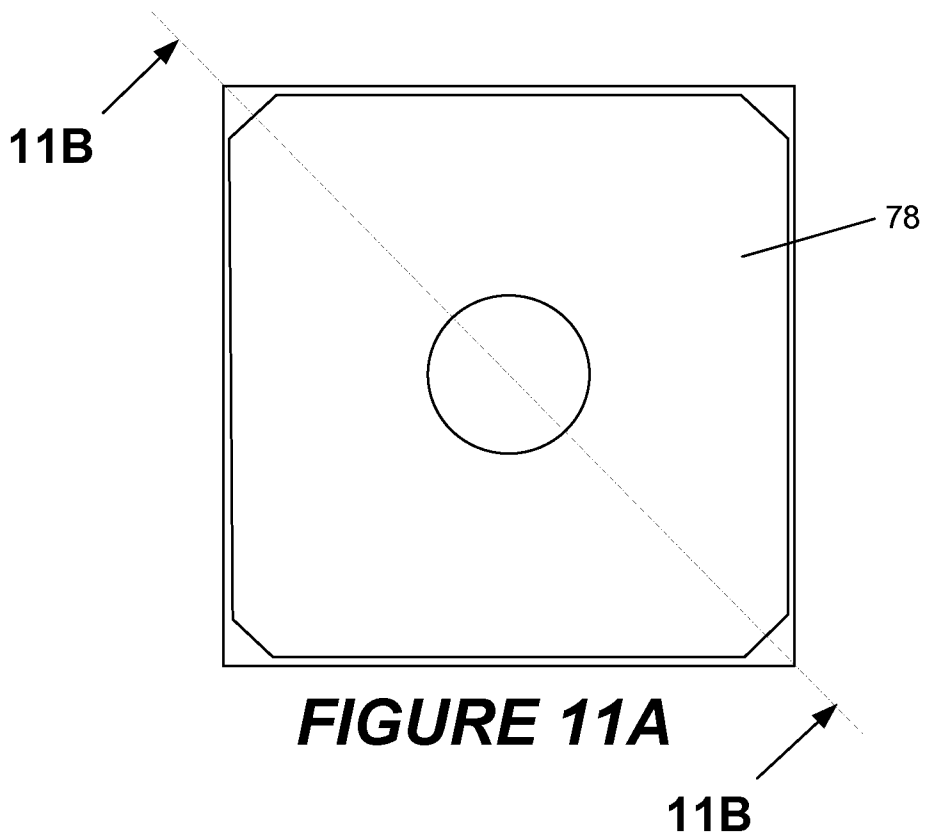
**FIGURE 9**

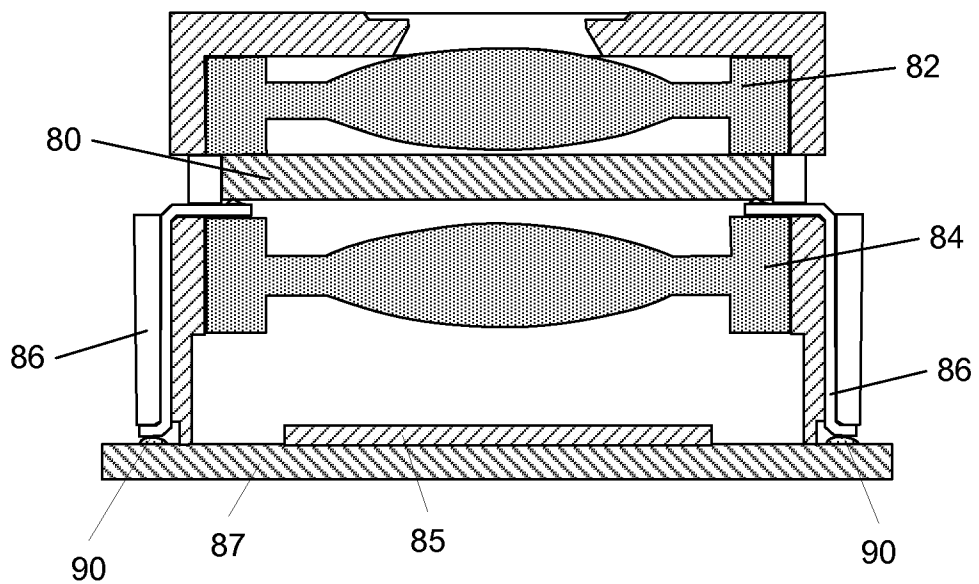
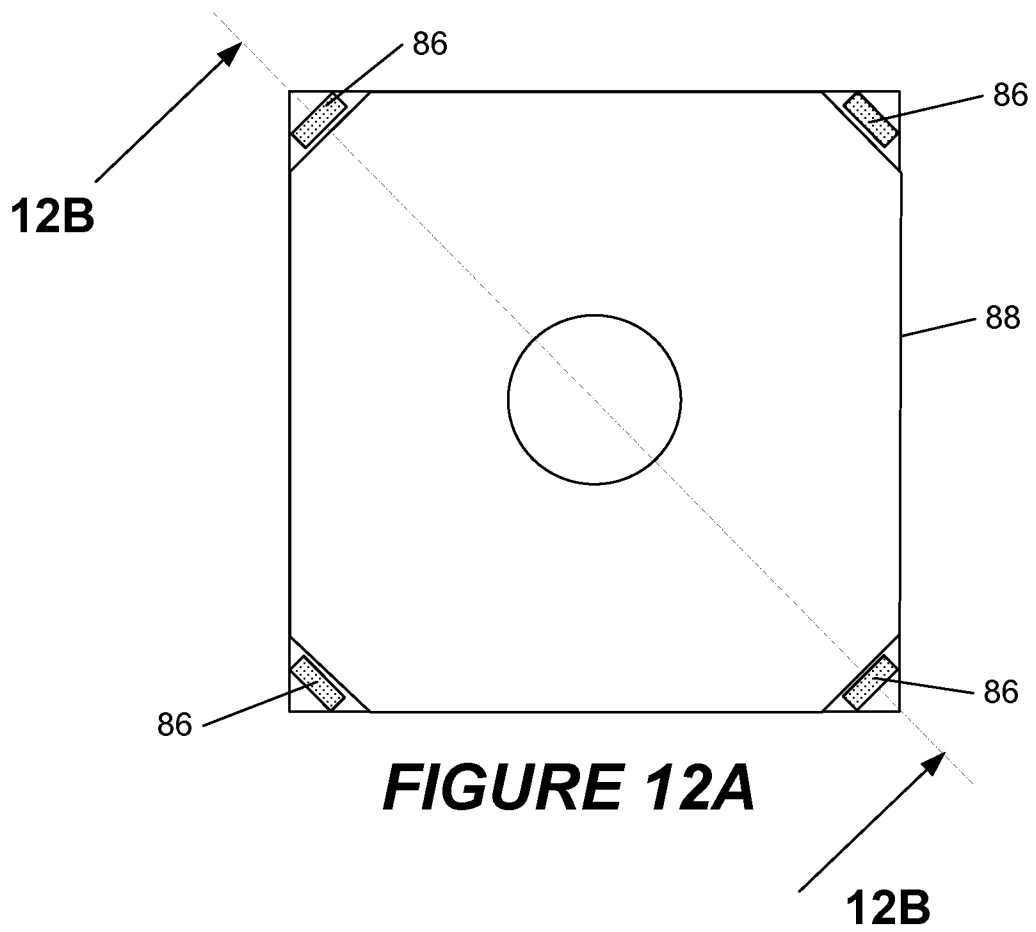


**FIGURE 10A**

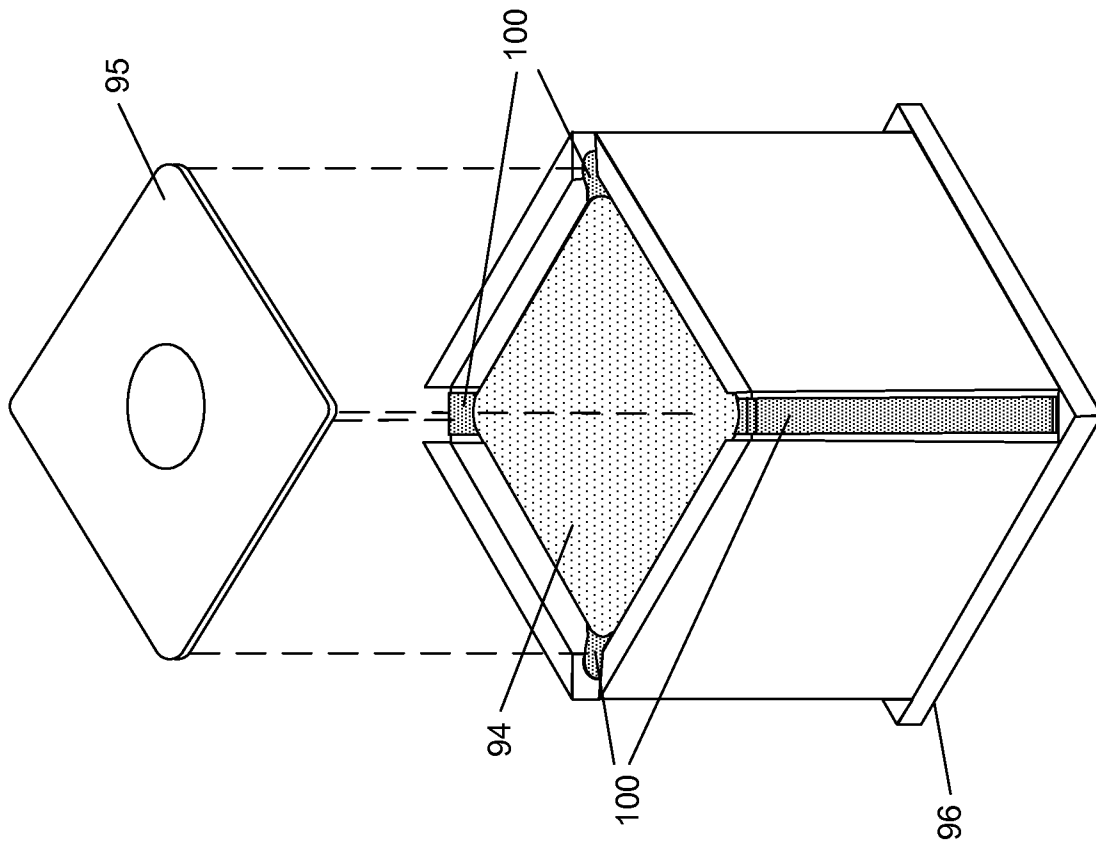


**FIGURE 10B**

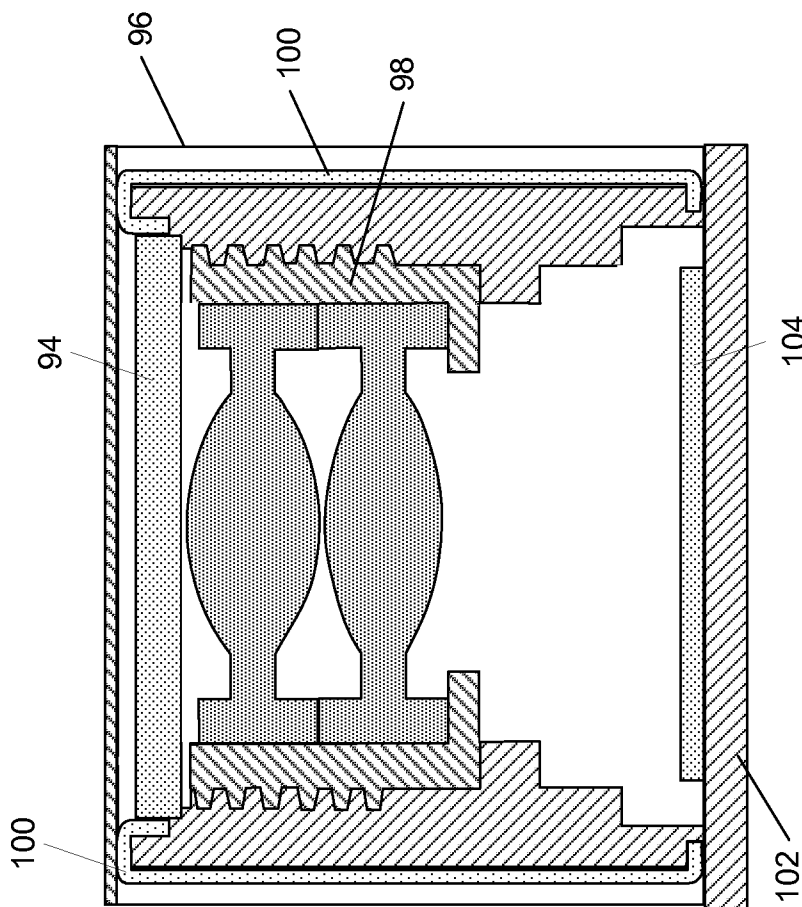




**FIGURE 12B**



**FIGURE 13B**



**FIGURE 13A**

INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US2010/033347

A. CLASSIFICATION OF SUBJECT MATTER  
IPC(8) - G02F 1/1333 (2010.01)  
USPC - 349/200  
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)  
IPC(8) - G02F 1/13, 133, 1333, 1345 (2010.01)  
USPC - 349/33, 193, 200; 359/721, 819, 822, 823-827, 829

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)  
PatBase, Google Patents

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008/0088756 A1 (TSENG et al) 17 April 2008 (17.04.2008) entire document	1-4, 6-7, 11, 15-16, 18, 22
---		
Y		5, 8-10, 12-14, 17, 19-21, 23-25
Y	US 7,469,100 B2 (TOOR et al) 23 December 2008 (23.12.2008) entire document	5, 12-14, 17, 23-25
Y	US 5,808,679 A (SHIH) 15 September 1998 (15.09.1998) entire document	8-9, 19-20
Y	US 6,359,674 B1 (HORIUCHI) 19 March 2002 (19.03.2002) entire document	10, 21

Further documents are listed in the continuation of Box C.

\* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 11 August 2010	Date of mailing of the international search report <b>23 AUG 2010</b>
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Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774
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INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2010/033347

**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.:  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
  
3.  Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

**Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)**

This International Searching Authority found multiple inventions in this international application, as follows:  
See Extra Sheet

1.  As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2.  As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3.  As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:  
1-25

- Remark on Protest**
- The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
  - The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
  - No protest accompanied the payment of additional search fees.