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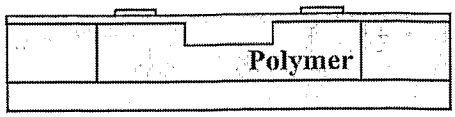
(54) **Title:** A DEVICE FOR PROVIDING STABILIZED IMAGES IN A HAND HELD CAMERA



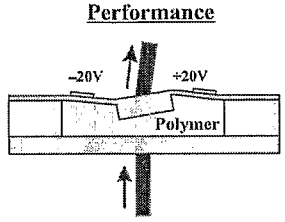


Fig. 3

(57) **Abstract:** The present invention provides image stabilization by altering the direction of the optical axis through a flexible lens body by activating actuators attached to the flexible lens body, wherein the amount of applied voltages onto the actuators are proportional to signals provided by motion sensors sensing yawing and pitching movements, respectively.

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A device for providing stabilized images in a hand held camera

The present invention is related to image stabilization of handheld digital cameras, and especially to a device providing image stabilization by applying control signals on actuators attached to a flexible lens body, wherein squeezing of the flexible lens body by the actuators provides a shift in the direction of the optical axis through the lens body in accordance with the control signals that are counteracting the effects of unintended movements or vibrations of the handheld camera.

Trembling of the hand, vibrations in the ground or in a floor of a building, or other similar small rapid movements from or through a person or a camera stand, holding a camera, such as a still photography camera or a video camera, are usually unintended movements causing blurring of the pictures since the shutter speed is finite, and the image scene is swept over the image sensor by the unintended movement of the camera. In order to compensate for such unintended movements very high shutter speeds could be used. However, this would affect the low brightness threshold of the camera since less light is captured due to the higher shutter speeds. There are also physical limitations with regard to how fast a shutter can be moved. Digital cameras do also have problems related to the background noise level and read-out speed that affects the maximum possible shutter speed of the camera. In prior art there are known some solutions providing image stabilization by either using a hardware system, or a software program for post processing of captured and stored digital images, or as a combination of hardware and real time software, providing an elimination or compensation of the unintended movements in the captured images.

Currently known methods for image stabilization of digital cameras (still picture and video cameras) typically uses optical lens elements inserted into the light path which are moved laterally by a mechanical mechanism driven by an external motor, for example piezo actuators, voice coils or step motors, and are characterized by a complex arrangement with many parts. For example, a gyro can provide signals providing control signals that counteract unintended movements by moving an optical lens element in an opposite direction than the unintended movement. Other prior art methods uses software algorithms and reduces image blurriness after image capture, but this scheme provides no improved optical quality of the captured image frames, and introduces in stead other image artifacts reducing the quality of the pictures further.

Prior art solutions providing a mechanically driven mechanism makes the camera system larger and more complex to build. The large number of parts does also pose a reliability risk. Software solutions providing an image analysis and filtering of captured and stored digital images tends to crop the images, and then often extrapolate lost image parts at the edges of the image to hide the unintended movements. In astronomy it is often used an orthogonal transfer CCD chip that actually shifts the image within the CCD chip itself while the image is captured based on an online analysis of the apparent motion of celestial objects being observed. Solutions provided for by camera manufactures such as Sony, Nikon, Konica Minolta etc. moves mechanically either the image sensor, or have a floating lens element being moved according to control signals provided for by gyroscopic sensors, sensing both the event and direction of small rapid unintended movements, wherein the unintended motion is characterized by providing a sensor signal above a preset threshold level related to speed, direction and intensity (acceleration and duration) of the movement.

Recent developments of flexible lens bodies provide compact lens assemblies with auto focus capabilities. For example, the Norwegian patent applications No. 20070803 and No. 20065238 provides examples of such devices. The present inventors has realized that these types of flexible lens assemblies may be modified and used to provide a simple, compact and easy manufacturability of systems for image stabilization. The optical image stabilizer according to the present invention overcomes the complexity of prior art solutions by providing actuators in contact with a flexible lens body providing a shifting of direction of the optical axis through the lens body, and hence the position of a crossing point between the optical axis and a surface of an image sensor, counteracting the movements of the unintended rapid movements. The shift of optical axis direction is obtained by "squeezing" the flexible lens body by activating the actuators according to control signals provided for by motion sensors, for example a gyroscopic sensor system as known in prior art.

According to an aspect of the present invention, image stabilizers provided for by flexible lens assemblies are suitable for wafer level manufacturing, which enables a new class of fully automated integrated camera solutions.

According to an example of embodiment of a device according to the present invention, the example of embodiment enables compact cameras for e.g. cameras for mobile phones to increase the exposure time without increased blurring due to small rapid unintended movements, since the device compensates the movements. Increasing the

exposure time for e.g. CMOS digital cameras implies a strongly increased signal to noise level, less background noise for pictures taken under dark conditions and reduces thresholds used for a required brightness. It also implies that a camera can be designed for a higher F-number, while still capturing the same amount of light (over a longer period of time), compared to lower F-number solutions, which will enable reduced size, complexity and cost of the camera lenses compared to the present prior art lenses.

According to an example of embodiment of the present invention, a device for providing stabilized images in a hand held camera comprises a flexible lens body arranged in between at least one actuator providing a squeezing of the flexible lens body when applied voltages activates the at least one actuator, wherein the activating voltages alters directions of light passing the lens body proportionally to signals provided by motion sensors sensing yawing and pitching movements, respectively, of the camera.

According to an example of embodiment of the present invention, a device comprises side walls bounding a cavity filled with transparent polymer on top of a transparent support, wherein a bendable transparent cover is arranged on top of the side walls and the polymer comprising a centrally attached transparent prism, located in between piezo electric actuators located on top of the transparent cover.

According to an example of embodiment of the present invention, a device comprises a centrally attached prism formed as a cylindrical lens, wherein two separate piezo electric actuators, one on each side of the cylindrical lens is providing a one dimensional displacement of light passing the device.

According to an example of embodiment of the present invention, wherein a centrally attached prism is a spherical lens, wherein four separate piezo electric elements are arranged in a quadratic pattern around the spherical lens, providing a two dimensional displacement of light passing the device.

According to an example of embodiment of the present invention, a device comprises the motion detectors that are gyroscopic sensors.

According to an example of embodiment of the present invention, a device comprises a motion detector that provides a signal only when the signal level is above a preset threshold level.

According to an example of embodiment of the present invention, the signals from the motion detectors are combined with signals from a tracking device providing a projection of an object onto substantially the same location on an image sensor surface when the device is moved for following the movements of a fast moving object viewed through the device.

According to an example of embodiment of the present invention, a device for providing stabilized images in a hand held camera comprises a flexible body with a light reflecting coating on an outwardly facing surface arranged in between at least one actuator providing a squeezing of the flexible body when applied voltages activates the at least one actuator, wherein the activating voltages alters directions of incident light being reflected by the body proportionally to signals provided by motion sensors sensing yawing and pitching movements, respectively, of the camera.

According to an example of embodiment of the present invention, a device comprises side walls bounding a cavity filled with polymer on top of a support, wherein a bendable cover is arranged on top of the side walls and the polymer is comprising a centrally attached body with a reflecting coating on an outwardly facing side of the body, located in between piezo electric actuators located on top of the cover.

According to an example of embodiment of the present invention, two separate piezo electric actuators, one on each side of the centrally attached body is providing a one dimensional displacement of incident light being reflected from the device.

According to an example of embodiment of the present invention, four separate piezo electric actuators are arranged in a quadratic pattern around the centrally attached body providing a two dimensional displacement of incident light being reflected from the device.

Figure 1 depicts an example of prior art image stabilizing arrangements in a camera.

Figure 2 depicts another example of prior art image stabilizing arrangements in a camera.

Figure 3a and 3b depicts an example of embodiment of the present invention.

Figure 4 depicts another example of embodiment of the present invention.

Figure 5 depicts another example of embodiment of the present invention comprising auto focus capabilities.

Figure 6 depicts another example of embodiment of the present invention.

Figure 7 depicts another example of embodiment of the present invention.

Figure 1 illustrates the principle arrangement of an image stabilizer moving a lens element according to signals from motion sensor elements, as known in prior art. As depicted in figure 1, a camera house 10 may be moved unintended horizontally around the Y axis denoted yawing, and/or around the X axis which is a movement denoted pitching. An angular velocity sensor 1 located along the Y axis direction senses yawing while another velocity sensor 2 located along the X axis senses pitching. According to signal magnitudes from these sensors, respective actuators 11 and 12 respectively shifts the VR Lens element in the X and Y directions compensating the unintended motions detected by the angular velocity detectors 1 and 2.

Figure 2 illustrates the principles of an image stabilizing system moving a CCD image sensor chip according to gyroscopic signal processing.

An ordinary person skilled in the art understands that such arrangements as illustrated in figure 1 and figure 2, although providing functional solutions to the image stabilizing problem, indeed are complex solutions that are difficult to manufacture. The key problem for providing image stabilization is to arrange movements of the crossing point between light in the optical axis and the surface of the image sensor in a counteracting motion relative to the detected unintended motions, and not the detection of unintended motions as such. For example, modern semi conductor technology and micro electronic mechanical systems (MEMS) systems etc. provides capabilities for providing miniaturized gyroscopic sensors that easily can be integrated into digital cameras for example, as known to a person skilled in the art.

Figure 3a and 3b illustrates an example of embodiment of the present invention. According to the present invention, correcting movements of an optical axis through a lens assembly may be accomplished by an arrangement as depicted in figure 3a. A transparent flexible polymer is arranged in a cavity 21 bounded by walls 22, a transparent support 23 and a thin bendable transparent cover 26 (for example a thin

glass plate) arranged with a centrally located transparent prism 25 in between at least two piezo electric actuators 24. When for example a negative voltage is applied onto one of the two piezo electric actuators, and a positive voltage is applied onto the other piezo electric actuator, the transparent prism 25 is tilted as shown in figure 3b. As readily can be understood by an ordinary person skilled in the art, by adjusting the applied voltages onto the piezo electric actuators, the amount of tilting, and hence the displacement of the optical axis through the assembly, may be controlled according to motion sensors providing signals that are in accordance with detected unintended movements, thereby providing means for counteracting such unintended movements by shifting the position of the crossing point between the optical axis and a surface of the image sensor. The amount of shifting necessary is proportional to the distance between the device depicted in figure 1 and the surface of the image sensor (not shown). In practical embodiments of these principles, the amount of applied voltages onto the piezo electric actuators can be scaled by programmable voltage sources, programmable or fixed attenuators etc., as known to a person skilled in the art.

Figure 4 illustrates another example of embodiment of the present invention, wherein the prism 25 in figure 3a and 3b is replaced with a body 30 (can be the prism as illustrated in figure 3a and 3b) coated with a light reflecting material on the outwardly facing surface of the body 30. When the piezo electric actuators 24 are tilting the body 30, incident light onto the reflecting surface of the body 30 changes its reflected direction. As can readily be understood by an ordinary person skilled in the art, this arrangement can be used to adjust the crossing point between the reflected light from the body 30 and an image sensor surface to counteract effects of unintended movements detected by motion sensors, for example. The amount of voltages applied onto the piezo electric actuators is proportional to the amount of displacement necessary to move the crossing point to counteract the unintended movement.

Figure 5 illustrates an example on how an electronic circuitry may be arranged to provide the voltages onto the piezo electric actuators 24. The actual electronic circuitry or configuration of the circuitry can depend on the type of sensor that is used to detect the unintended movements. However, it is within the scope of the present invention that any type of sensors and electronic circuitry, including digital signal processors, micro controllers and microprocessors as well as discrete components, analog as well as digital components, can be used as long as the circuitry applies voltages onto the actuators in a fashion providing a tilting of the prism 25 or the body 30 counteracting the effects of the unintended movement that is detected.

Figure 6 illustrates another example of embodiment comprising an image stabilizing arrangement as illustrated in figure 3 together with a lens assembly providing auto focus capabilities. The electronic circuitry is arranged to provide both image stabilizing signals as well as providing a shift of the focus point. The lens arrangement providing auto focus capabilities is disclosed for example in the Norwegian patent application No. 20070803.

Figure 7 illustrates different examples of arranging a prism 25 (or a body 30 coated with a light reflecting material), in between different geometries of actuators 24 providing one dimensional tilting or two dimensional tilting of the prism 25 or body 30, respectively. Figure 7a illustrates a one dimensional tilting capability, while figure 7b and 7c illustrates two dimensional tilting capabilities. If the arrangement depicted in figure 7a is to be used to counteract yawing and pitching, a stack of two embodiments as illustrated in figure 7a could be provided, wherein one of the embodiments controls yawing while the other controls pitching, for example.

The different examples of embodiments of the present invention disclosed above provides a control of the crossing point between the light passing through the lens body (or direction of reflected light) and a surface of the image sensor in the camera or video recorder. According to another aspect of the present invention, other movements that are intended may cause the same type of blurriness that unintended movements may provide in images. Such intended rapid movements can stem from fast moving objects that are photographed or video recorded, for example such as a fast running formula 1 racing car. According to another example of embodiment of the present invention, a tracking device may be used to provide regulating voltages onto the piezo electric actuators according to the present invention. When a fast moving object is photographed or filmed by a video camera, the person holding the camera must follow the object as its moves by turning the camera in the direction of the movement. Due to the high speed of the fast moving object this can cause a jogging movement of the camera. This jogging will manifest itself in the images or video streams as blurriness in the images.

According to an example of embodiment of the present invention, a tracking device is used together with an embodiment of the present invention, for example as depicted in figure 3a or 4a, that will eliminate the problems related to photographing or filming fast moving objects. As known to a person skilled in the art, a tracking device allows an operator of a system comprising a camera or video recorder to lock a marker (cursor)

onto an object viewed through the camera or video recorder, thereby enabling the system to "follow" by turning the camera or video recorder as the marked object moves across a scene. The turning of the camera or video recorder is provided for by a camera platform attached to the camera comprising motors controlled by signals related to the detected movements of the locking marker (and thereby the movement of the locked object) across the surface of an image sensor in the came rear. The locking can be obtained by software detecting a contour of the object that the marker is pointing to, and then detecting movements in any direction of the contour by detecting shifting values of pixels in the edge areas of the locked object, as known to a person skilled in the art. When a locked object moves outside the boundaries of the image sensor surface, signals are generated that moves the camera or video recorder platform such that the object still is inside the surface of the image sensor.

The inventors of the present invention have realized that these principles of locking a marker onto an object may be utilized together with embodiments of the present invention to counteract the problems of photographing or filming fast moving objects. The tracking device according to the present invention comprises a selecting and locking mechanism of an object as known in the prior art. For example, a cursor can be used to select an object for locking through the viewfinder of a digital camera. However, this example of embodiment of the present invention does not comprise a motorized camera platform. When the fast moving object starts moving across the image sensor surface of the camera, signals are generated in the tracking device providing information of the movements of the locked object, such as speed, direction and intensity (acceleration) of the locked object. By transforming this information into voltages applied onto the piezo electric actuators according to the present invention, the movement of the fast moving object is counteracted such that the imaged object itself is always projected onto the same area of the surface of the image sensor. When the object starts to move, ore moves outside the viewfinder of the camera, the person holding the camera will follow the object by moving the camera. However, since this example of embodiments locks the object to the same area on the surface of the image sensor, this following movement by hand that usually provides a jogging sensation in the images is eliminated.

According to another aspect of the present invention, embodiments of the present invention may be provided for by wafer level manufacturing. According to an example of manufacturing according to the present invention, a plurality of devices according to the present invention may be defined by providing a plurality of sidewalls 22, for

example in a matrix pattern, on top of a transparent support 23. A polymer can then be filled into the plurality of cavities defined by the matrix pattern. Thereafter, a glass cover 26 may be assembled on top of the polymer and side wall matrix. A glass prism 25 may be an integral part of the glass cover 26, or may be assembled onto the glass cover 26 before the glass cover is arranged on top of the side wall matrix and polymer. A plurality of glass prisms 25 may be arranged in a similar matrix pattern on the glass cover 26, at positions consistent with the cavities bounded by the side walls 26 provided for by the matrix pattern. The piezo electric actuators 24 can likewise be arranged onto the glass cover 26 before or after assembly of the glass cover on top of the side walls 26, as known to a person skilled in the art. After the assembly process is finished, each device in the matrix pattern may be individualized by sawing along the matrix directions in the middle of each respective section of the side walls 22 surrounding each device provided by the matrix pattern.

C l a i m s :

1.
A device for providing stabilized images in a hand held camera, comprising a flexible lens body arranged in between at least one actuator providing a squeezing of the flexible lens body when applied voltages activates the at least one actuator, wherein the activating voltages alters directions of light passing the lens body proportionally to signals provided by motion sensors sensing yawing and pitching movements, respectively, of the camera.

2.
The device according to claim 1, wherein the device comprises side walls bounding a cavity filled with transparent polymer on top of a transparent support, wherein a bendable transparent cover is arranged on top of the side walls and the polymer comprising a centrally attached transparent prism, located in between piezo electric actuators located on top of the transparent cover.

3.
The device according to claim 2, wherein the centrally attached prism is a cylindrical lens, wherein two separate piezo electric actuators, one on each side of the cylindrical lens, providing a one dimensional displacement of light passing the device.

4.
The device according to claim 2, wherein the centrally attached prism is a spherical lens, wherein four separate piezo electric elements are arranged in a quadratic pattern around the spherical lens, providing a two dimensional displacement of light passing the device.

5.
The device according to claim 1, wherein the motion detectors are gyroscopic sensors.

6.
The device according to claim 1, wherein a motion detector provides a signal only when the signal level is above a preset threshold level.

7.

Device according to claim 1, wherein the signals from the motion detectors are combined with signals from a tracking device providing a projection of an object onto substantially the same location on an image sensor surface, when the device is moved to follow the movements of a fast moving object viewed through the device.

8.

A device for providing stabilized images in a hand held camera, comprising a flexible body with a light reflecting coating on an outwardly facing surface arranged in between at least one actuator providing a squeezing of the flexible body when applied voltages activates the at least one actuator, wherein the activating voltages alters directions of incident light being reflected by the body proportionally to signals provided by motion sensors sensing yawing and pitching movements, respectively, of the camera.

9.

The device according to claim 8, wherein the device comprises side walls bounding a cavity filled with polymer on top of a support, wherein a bendable cover is arranged on top of the side walls and the polymer comprising a centrally attached body with a reflecting coating on an outwardly facing side of the body, located in between piezo electric actuators located on top of the cover.

10.

The device according to claim 9, wherein two separate piezo electric actuators, one on each side of the centrally attached body is providing a one dimensional displacement of incident light being reflected from the device.

11.

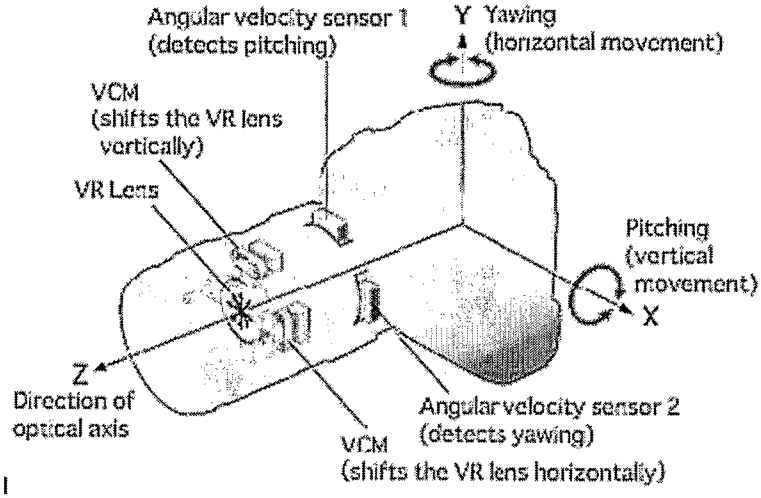
The device according to claim 10, wherein four separate piezo electric actuators are arranged in a quadratic pattern around the centrally attached body providing a two dimensional displacement of incident light being reflected from the device.

12.

The device according to claim 8, wherein the motion detectors are gyroscopic sensors.

13.

The device according to claim 8, wherein a motion detector provides a signal only when the signal level is above a preset threshold level.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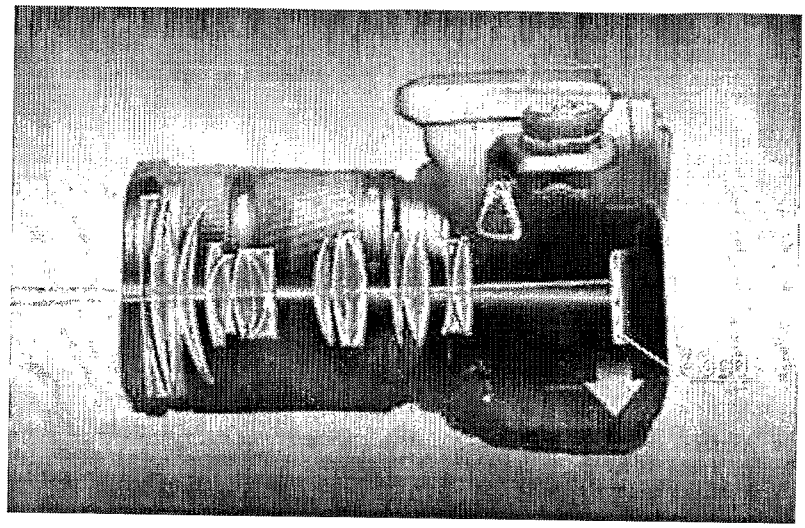
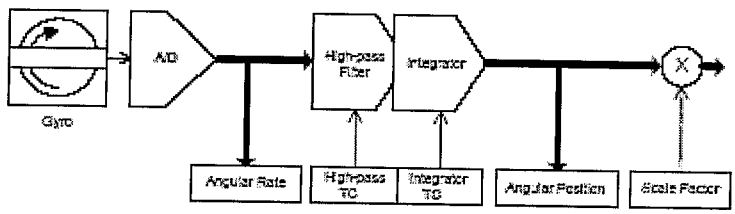
(horizontal movement)
VCM
(shifts the VR lens
vertically)
VR Lens
Pitching
(vertical
movement)
X
Z
Direction of
optical axis
Angular velocity sensor 2
(detects yawing)
VCM
(shifts the VR lens horizontally)

Fig. 1

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Integrator
X
Angular Rate
High-pass TC
Integrator TC
Angular Position
Scale Factor

Fig. 2

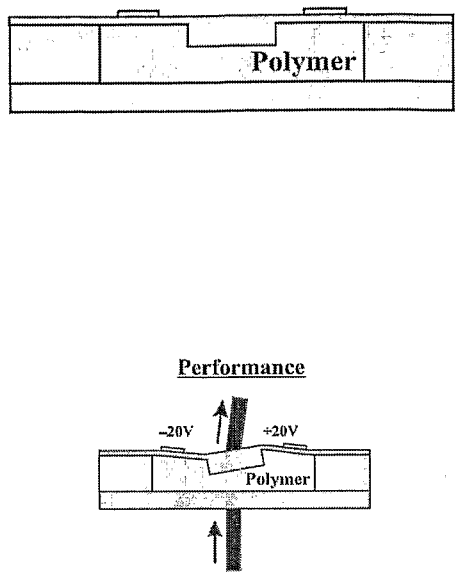

Fig. 3

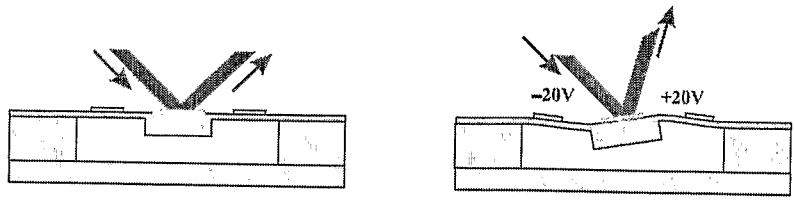

Fig. 4

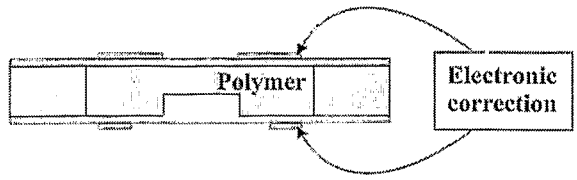

Fig. 5

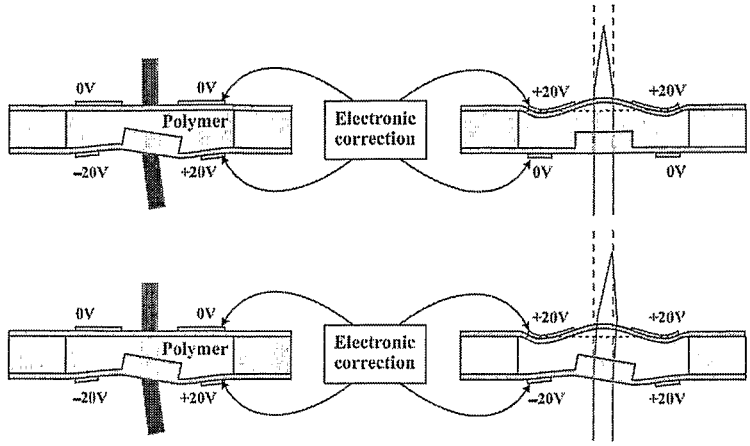
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Fig. 6

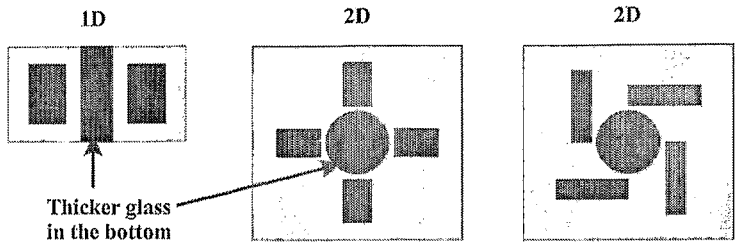

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO2008/000055

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:

1. A flexible lens body that alters the direction of light according to applied voltages proportional to signals from motion sensors, to correct for unintended movement of camera. Claims 1-7.
2. A flexible reflective body that alters the direction of light according to applied voltages proportional to signals from motion sensors, to correct for unintended movement of camera. Claims 8-13.

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 an additional fee, this Authority did not invite payment of any additional fee.

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.:

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.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO2008/000055

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet
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: G02B, G03B

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

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6307678 B2 (KOSAKA, A ET AL), 23 October 2001 (23.10.2001), column 3, line 7 - line 14; column 6, line 30 - line 32, column 1, paragraph 2, clai m 5, abstract --	1-7
X	US 20040201901 A1 (NAGATA, T), 14 October 2004 (14.10.2004), paragraph [0524], figure 26, abstract --	8-13
X	US 5517238 A (HIRASAWA, M), 14 May 1996 (14.05.1996), column 1, line 20 - line 30, figure 4, claims 1,5, abstract --	1-7

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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