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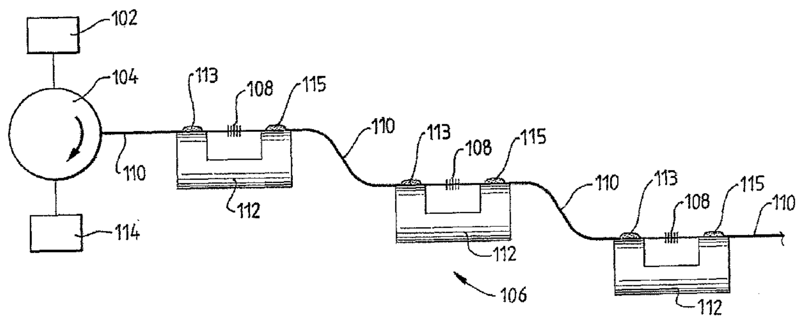

(57) Abstract: An apparatus comprising a light guide (110) incorporating a Bragg grating. The apparatus also comprises a moveable wall portion which is coupled to the Bragg grating (108) so that a movement of the wall portion causes a force that effects a change in strain of the Bragg grating and thereby effects a change in an optical period of the Bragg grating. A temperature related change in the optical period of the Bragg grating is reduced by a temperature related change in the force on the Bragg grating by the moveable wall portion.

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AN OPTICAL DEVICE

Field of the Invention

The present invention broadly relates to an optical device and relates particularly, though not exclusively, to an apparatus for pressure sensing.

Background of the Invention

Pressure measurements are conducted in a variety of different media and for a variety of different purposes. For example, pressure is measured in open air, under water and in devices or machines. Mechanical or electronic devices typically are used for such pressure measurements.

Recently optical pressure measurement devices became popular in which an external pressure change effects a change in light interference conditions which can be detected. Such an optical device may comprise a fibre Bragg grating which has an optical response that depends on a strain of the Bragg grating. Specifically, if the strain is increased, a wavelength of a reflected light beam will shift to longer wavelengths.

Such optical devices have the advantage that they can be relatively small and may be manufactured from materials that are largely inert (such as glass) and not easily affected by many chemicals. However, temperature changes also effect a change in the interference conditions of such Bragg gratings. In general, the refractive index of such a Bragg grating will increase with increasing temperature and therefore the optical period, and hence the wavelength of the reflected beam, will also increase with increasing temperature. Consequently such optical devices can only provide reliable information about the pressure if the temperature is known. For many applications the detection of temperature changes may not be possible or convenient. There is a need for technological advancement.

Summary of the Invention

The present invention provides in a first aspect an optical device comprising:

a light guide,

a Bragg grating incorporated into the light guide,

a moveable wall portion coupled to the Bragg grating so that a movement of the moveable wall portion causes a force that effects a change in strain of the Bragg grating and thereby effects a change in an optical period of the Bragg grating,

wherein a temperature related change in the optical period of the Bragg grating is reduced by a temperature related change in the force on the Bragg grating by the moveable wall portion.

The optical device typically is an apparatus for pressure sensing. The moveable wall portion typically has opposite first and second sides and is positioned so that a change in pressure at one of the sides relative to a pressure at the other side will move the moveable wall portion.

The optical device typically comprises an enclosed space and the moveable wall portion typically is positioned so that a change in external pressure will move the moveable wall portion. The optical device typically comprises an enclosure having the moveable wall portion and forming the enclosed space.

In this embodiment the dual function of the moveable wall portion, namely reducing a temperature related change in the optical period of the Bragg grating and causing a force on the Bragg grating in response to an external pressure change, facilitates a compact design of the optical device.

The optical device typically has a normal operating temperature and pressure range at which the Bragg grating is distorted, typically, but not exclusively, by the force caused by the moveable wall portion. The Bragg grating typically is distorted into the enclosed space.

The light guide typically is attached to a rigid portion of the enclosure at attachment regions between which a sensing region of the Bragg grating is defined. The or each light guide typically is secured in or on the rigid portion of the enclosure so that the rigidity of the rigid portion prevents that an axial force acting on the light guide external to the enclosure affects the optical response of the Bragg grating.

The optical device typically is arranged so that the force caused by a change in external pressure is a sideway-force on the Bragg grating.

The moveable wall portion typically is a diaphragm and, at ambient temperature and pressure, typically is positioned so that the diaphragm applies the force on the Bragg grating in a manner such that the distortion of the Bragg grating into the enclosed space increases. Consequently, a temperature related change in material properties of the diaphragm, such as a property related to the Young's modulus, thermal expansion or other such properties, typically reduces the force on the Bragg grating and thereby reduces a temperature related change in strain of the Bragg grating between the attachment regions caused by a thermal expansion of the Bragg grating.

Further, a temperature increase will typically result in an increase of a pressure in the enclosed space which typically will also reduce the force applied by the diaphragm on the Bragg grating and thereby reduces a temperature related change in strain of the Bragg grating between the attachment regions.

As the temperature related change in strain of the or each Bragg grating is reduced, the pressure measurement is largely independent from changes in temperature, at least over a predetermined temperature range, which has significant practical advantages.

The optical device may be used for pressure measurements in any environment, including for example in-vivo-environments, laboratories and wind tunnels.

The optical device may comprise an external catheter that may be arranged for insertion into a human body. Further, the optical device may comprise a portion comprising an X-ray opaque material which enables imaging the position of the optical device in the human body.

The enclosure typically is arranged and the Bragg grating typically is positioned so that the optical response of the Bragg grating is a non-linear function of the temperature. In this case a plot of the optical period of the Bragg grating as a function of the temperature typically has at least one valley and may have, at least for one temperature range, a combined quadratic and linear dependency on the temperature. An optical response of the Bragg grating typically has a linear dependency on the temperature and on axial strain, but the strain on the Bragg grating attached to the enclosure typically has a quadratic dependency on the temperature. Consequently, if the Bragg grating is arranged so that a change in temperature of the enclosure also causes a change in strain, the optical response of the Bragg grating will have a combined quadratic and linear dependency on the temperature.

The normal operating temperature of the optical device may be a temperature at which the optical period has a minimum in the valley and by selecting a strain applied to the Bragg grating it is possible to select the normal operating temperature. The enclosure and the Bragg grating typically are arranged so that the optical period of the Bragg grating does not change by more than 0.001nm if the temperature changes by ±1 degree and no more than 0.05nm if the temperature changes by ±10 degrees from the normal operating temperature of the optical device.

The light guide with the Bragg grating may be in direct contact with the diaphragm. In one specific embodiment of the present invention the light guide with the Bragg grating is indirectly coupled to the optical device and has an anvil positioned between the diaphragm and the Bragg grating.

The Bragg grating may be positioned on the diaphragm and outside the enclosure. Alternatively, the Bragg grating may be positioned within the diaphragm or on the diaphragm and inside the enclosure.

The enclosure may comprise a casing that is formed from a rigid material and the moveable wall portion, for example provided in the form of the diaphragm, may be positioned opposite a rigid wall portion of the casing. In this case the optical device is suitable for sensing the pressure change on one side of the optical device. Alternatively, the moveable wall portion may surround a portion of the enclosed space of the enclosure. In this case the Bragg grating typically also surrounds at least a portion of the enclosed space.

In another specific embodiment the moveable wall portion and the respective Bragg grating circumferences the entire enclosed space and the optical device is arranged so that pressure changes can be sensed in a region that radially surrounds the optical device.

In one specific embodiment the optical device comprises a series of Bragg gratings with corresponding enclosures. In this embodiment, the Bragg gratings and the light guide comprise one optical fibre. The optical fibre is in this embodiment attached to the rigid portions of the respective enclosures, but is flexible at regions between two enclosures of the series so that the optical device is articulated.

The enclosure typically is filled with a compressible fluid such as air.

The light guide may comprise an optical fibre such as a single mode optical fibre in which the or each Bragg grating may have been written. As optical fibres are known to cause very little signal loss per length, the optical device can have a relatively long optical fibre lead and an optical analyser for analysing the response from the or each Bragg grating may be remote from the or each Bragg grating, such as 1m, 10m, 1km or 100km remote from the or each Bragg grating.

Alternatively, the optical device may comprise a plurality of Bragg gratings associated with a plurality of respective light guiding arms of the optical device.

The optical device may be arranged so that the optical response from the or each Bragg grating can be detected by detecting light that is reflected back from the or each Bragg grating. In this case the light guide typically is arranged so that the light is guided to and from the or each Bragg grating by the same optical fibre portion.

The optical device may also be arranged so that the optical response from the or each Bragg grating can be detected by detecting light that is transmitted through the or each Bragg grating. In this case the light guide typically comprises at least one optical fibre for guiding the light to the or each Bragg grating and at least one other optical fibre for guiding the light from the or each Bragg grating.

In one specific embodiment of the present invention the device comprises a series of Bragg gratings for distributed pressure sensing. Each Bragg grating of the series typically is arranged do give a different optical response so that light guided through the or each Bragg gratings is wavelength division multiplexed. With such a device it is possible to detect pressure changes at a series of positions which correspond to the positions of the Bragg gratings. As each Bragg grating gives a different response, it is possible to associate a particular pressure change with a respective position within the body.

In a variation of this embodiment the optical device also comprises a plurality of the Bragg gratings, but at least some of the Bragg gratings are substantially identical and typically give the same response if the strain conditions are the same. Using time division multiplexing techniques, the position of a particular Bragg grating may be estimated from a time at which an optical response is received.

In one embodiment the or each Bragg grating and the light guide comprises one optical fibre. For example, the or each Bragg grating may be written in the optical fibre and light guide may be integrally formed. Alternatively the optical fibre may comprise portions that are spliced together.

The present invention provides in a second aspect a method of fabricating an apparatus for pressure sensing, the method comprising:

providing a light guide having a Bragg grating,

selecting a design for a moveable wall portion, the moveable wall portion having opposite first and second sides,

positioning the moveable wall portion so that a change in pressure at one of the side relative to a pressure at the other side will move the moveable wall portion,

selecting a distortion for the or each Bragg grating, and

coupling the Bragg grating to the moveable wall portion so that the Bragg grating has the selected distortion and the movement of the moveable wall portion causes a force that effects a change in strain of the Bragg grating,

wherein the design of the moveable wall portion and the distortion of the Bragg grating are selected so that a temperature related change in optical period of the Bragg grating is reduced by a temperature related change in the force on the Bragg grating.

The apparatus typically is fabricated so that the apparatus has an enclosed space and the Bragg grating is distorted into the enclosed space.

The step of selecting a design of the moveable wall portion typically comprises selecting a thermal expansion coefficient of a material for forming the moveable wall portion.

The step of selecting a design of the moveable wall portion typically comprises selecting a Young's modulus for the moveable wall portion, which typically is a diaphragm.

The present invention provides in a third aspect an apparatus for pressure sensing fabricated by the above-defined method.

The invention will be more fully understood from the following description of specific embodiments of the invention. The description is provided with reference to the accompanying drawings.

Brief Description of the Drawings

Figure 1 (a) and (b) shows a sensing system according to a specific embodiment of the present invention,

Figures 2 (a) and Figures 2 (a) and (b) show an optical device according to an embodiment of the present invention and Figure 2 (c) shows an alternative component of the apparatus for pressure sensing,

Figure 3 shows a plot of Bragg grating responses as a function of temperature,

Figure 4 (a) and (b) shows an optical device according to a specific embodiment of the present invention,

Figure 5 (a) and (b) shows an sensing apparatus according to a further specific embodiment of the present invention,

Figure 6 shows an optical device according to another specific embodiment of the present invention and

Figure 7 shows an optical device according to yet another specific embodiment of the present invention.

Detailed Description of Specific Embodiments

Figures 1, 2 and 3 - 7 show embodiments of the optical device or sensing system in which the optical device is an apparatus for pressure sensing. It is to be appreciated, however that the present invention has broader applications and the optical device may not necessarily be a pressure sensing apparatus.

Referring initially to Figure 1 (a), a system for pressure sensing according to a specific embodiment of the present invention is now described. The system 100 comprises a light source 102 which in this embodiment is a broadband light source commonly referred to as a "white" light source even though the light that is emitted by the light source 102 may have any wavelength range.

The light is directed via optical circulator 104 to an apparatus for pressure sensing 106. In a variation of this embodiment the circulator 104 may be replaced by an optical coupler, an optical splitter or an optical beam splitter.

The apparatus 106 may comprise a catheter (not shown) for insertion into the human body. Further, the apparatus 106 typically comprises an X-ray opaque material, such as a metallic material, for locating the apparatus 106 in the human body.

In this embodiment the apparatus 106 comprises a series of Bragg gratings 108 which are formed in an optical fibre and which are linked by optical fibre portions 110. Each Bragg grating 108 is in this embodiment positioned in association with an enclosure 112. Each enclosure 112 has a movable wall portion which is provided in the form of a diaphragm (not shown). In this embodiment, the optical fibre 110 is rigidly connected at end-portions 113 and 115 of a respective enclosure 112 so that a respective Bragg grating 108 is positioned between two end portions. Each Bragg grating is positioned on or near a respective diaphragm such that an external pressure change effects movement of the diaphragm which in turn will apply a strain to the Bragg grating 108. The strain causes a change of an optical property of the Bragg grating 108, such as a change of an optical path length, which influences an optical response of the grating 108 to light guided to the Bragg grating 108. Consequently it is possible to sense a pressure change from analysing the optical response from the Bragg gratings.

It will be appreciated, that in alternative embodiments each Bragg grating 108 may be positioned within or below a respective diaphragm. The remaining walls of the enclosure 112 are formed from a rigid material, such as silicon, a plastics or metallic material (for example stainless steel, invar, tungsten, or kovar), or any other suitable rigid material. In this embodiment the apparatus 106 comprises a series of three Bragg gratings 108. In alternative embodiments the apparatus 106 may comprise any other number of Bragg gratings at any fixed or variable pitch.

In this embodiment each Bragg grating 108 of the series has a slightly different refractive index variation so that each Bragg grating 108 has an optical response that has a slightly different spectral response. The light that is produced by light source 102 and that is directed to the Bragg gratings 108 therefore causes three unique responses from the Bragg gratings 108 which are directed via the optical circulator 104 to optical analyser 114 for optical analysis. Such a procedure is commonly referred to as wavelength division multiplexing (WDM). The Bragg grating may also effect optical responses which overlap in wavelength or frequency space as long as sufficient information is known about each Bragg grating to allow the signals to be successfully deconvolved.

As in this embodiment each Bragg grating 108 causes a different response, it is possible to associate a particular response with a position along the apparatus 106. Consequently it is possible to perform distributed pressure measurements and detect relative pressure difference between the positions of the Bragg gratings 108 in the series. The combined response from the Bragg gratings is wavelength division multiplexed and the optical analyser 114 uses known wavelength division de-multiplexing techniques to identify the responses from the respective grating positions. Suitable software routines are used to determine a pressure or pressure distribution from the optical responses received from the Bragg gratings. Pressure measurements typically include calibrating the apparatus.

In a variation of this embodiment at least some of the Bragg gratings 108 may be identical and consequently, if the strain conditions are the same, their optical response will also be the same. In this case a pulsed light source may be used to guide light to the Bragg gratings and the positions of the Bragg gratings may be estimated from a time at which the responses are received by the optical analyser 114.

In one particular example the reflectivity of each Bragg grating 108 is chosen so that each response has, at the location of the optical analyser 114, approximately the same intensity.

It will be appreciated that in a further variation of this embodiment the apparatus may be arranged so that responses from respective Bragg gratings can be analysed by receiving light that is transmitted through the Bragg gratings 108. For example, in this case the apparatus 106 typically is arranged so that light is guided from the light source 102 through the Bragg gratings 108 and then directly to the optical analyser 114.

In this embodiment each Bragg grating 108 is written into an optical fibre and spliced between fibre portions 110. It will be appreciated, that in alternative embodiments the Bragg gratings 108 and the fibre portions 110 may be integrally formed from one optical fibre. The same optical fibre may be used for writing respective refractive index variations for each grating so that spaced apart Bragg gratings are formed separated by fibre portions. In this embodiment the enclosures 112 comprise a rigid material while the fibre portions 110 are relatively flexible. Consequently the apparatus 106 is an articulated device. Figure 1 (b) shows the system for pressure sensing 100 also shown in Figure 1 (a), but the optical fibre 110 is bent between the enclosures 112 of the articulated device.

In variations of this embodiment the apparatus may comprise a plurality of Bragg gratings associated with respective optical fibres that are arranged in parallel.

Figures 2 (a) and (b) show schematically an apparatus for pressure sensing in more detail. The apparatus 120 comprises an optical fibre 122, a Bragg grating 124 and an enclosure 126 which includes a body 128, a diaphragm 130 and an anvil 132. The enclosure 126 encloses a space 134 and is arranged so that a change in external pressure will change the enclosed space 134 by deflecting the diaphragm

130 and the anvil 132 will increase the distortion of the Bragg grating 124. In this embodiment the Bragg grating 124 is distorted into the enclosed space 134 and the optical fibre 122 is attached to the enclosure 126, which is composed of a rigid material, at attachment regions 127 and 129.

In the example shown in Figure 2 (a) and (b) the distortion of the Bragg grating 124 causes a tensile strain of the Bragg grating 124. If the ambient temperature now increases from the normal operation temperature, a number of physical effects may take place. The optical period of the Bragg grating 124 will typically increase and the enclosed space 134 will tend to expand. Further, the diaphragm material, which typically is positioned so that the distortion of the Bragg grating is increased at a normal operating temperature, will tend to expand and/or the Young's modulus of the diaphragm material may decrease which in turn causes a decrease of the distorting force on the Bragg grating 124 and thereby counteracts the increase of the optical period. Hence, it is possible to influence the temperature dependency of optical responses by selecting materials having selected thermal behaviour.

Since typically the above physical processes influence the grating response as a function of temperature, it is possible to select a design for the apparatus a Bragg grating distortion so that the valley of the plot 140 can be shifted to wide range of temperatures. Further, it is possible to design the apparatus so that the plot 140 would have more than one valley and/or peak and hence provide an extended range over which acceptable athermal behaviour is achieved.

Figure 2 (c) shows an enclosure 133 which is a variation of the enclosure 126 shown in Figure 2 (a). The enclosure 133 has two portions 135 and 137 for securely fixing an optical fibre containing a Bragg grating and two recesses 139 and 141 for coupling the optical fibre in a flexible manner. The flexible coupling portions reduce bending forces at the portions 135 and 137 on the coupled Bragg grating.

It is to be appreciated that the apparatus shown in Figure 2 has only one of many possible designs. For example, the apparatus may not necessarily have an anvil but the Bragg grating may be mechanically distorted into the enclosed space without an anvil and in contact with the diaphragm. The optical fibre 122 containing the Bragg grating 124 is in this example secured on the enclosure at positions 127 and 129 so that the Bragg grating is located between positions 127 and 129 and an optical response of the Bragg grating 124 has a partially quadratic dependency on the temperature.

Figure 4 (a) and 4 (b) shows an apparatus for pressure sensing according to another embodiment of the present invention. In this embodiment the apparatus 200 comprises a Bragg grating 202 and a body 204. The Bragg grating 202 is formed in an optical fibre that comprises a core/cladding region 205 and a protective coating 206. The protective coating 206 has been stripped away in the area of the Bragg grating 202. The core/cladding region is attached to the body 204. In this embodiment the core/cladding region 205 is glued to the body 204 at regions 210 and 212. For example, the body may be formed from silicon, a plastics or metallic material, or any other suitable rigid material.

Figure 4 (b) shows an apparatus 220, a variation of the apparatus 200, with a diaphragm 214 applied to it. For example, the diaphragm 214 may be a cold or hot shrink tube which is inserted over the Bragg grating 202 and over the body 204 or an elastic material that stretches around the body 204. As the body 204 has a recess 216, an enclosed pressure sensitive space is formed at the recess 216 and below the diaphragm 214. The diaphragm 214 is composed of a flexible material such as a rubber or nylon material, a flexible metal foil or silicone foil. Similar to the embodiment shown in Figure 2, the Bragg grating 202 is slightly distorted into the enclosed space in the recess 216 (the distortion is indicated in Figure 4 (b) and not shown in Figure 4(a)).

Figure 3 shows plots of Bragg grating responses as a function of temperature. Plot 140 shows the response of a grating of the apparatus for pressure sensing shown in Figures 4 (a) and (b). In this example, the enclosure 204 is formed from stainless steel and the diaphragm is formed from polyolefin heat shrink. Figure 3 shows also a plot 142 for a typical Bragg grating that is not coupled to an enclosure and to a diaphragm and a plot 144 for a Bragg grating with the optical fibre being bonded to a stainless steel substrate and enclosed by Teflon tape (3M#60 PTFE tape).

In the example shown in Figure 4 the optical fibre containing the Bragg grating 202 is secured on the enclosure 204 at positions adjacent the Bragg grating 202 so that the Bragg grating is located between attachment regions. An optical response of the Bragg grating 202 has a partially quadratic dependency on the temperature. The refractive index of the Bragg grating 202 is approximately linearly dependent on the strain applied to the Bragg grating 202 and the optical response of Bragg grating 202 is dependent on both the refractive index and the optical period. The normal operating temperature of the apparatus is a temperature at which the optical period has a minimum in the valley and by selecting a strain and a distortion applied to the Bragg grating 202 it is possible to select the normal operating temperature. In this example the distortion of the Bragg grating 202 and the design of the enclosure 204 are selected so that the optical response of the or each Bragg grating does not change by more than approximately 0.001nm if the temperature changes by ± 1 degree from the normal operating temperature of the apparatus which typically is of the order of 77°C.

In this example the valley is positioned at approximately 77°C, but a person skilled in the art will appreciate that in a variation of this embodiment the apparatus may be designed so that the valley is positioned at approximately 37°C, or normal body temperature, which would then be the normal operating temperature.

Figure 5 (a) and 5 (b) shows apparatus 300 and 330 according to further embodiments of the present invention. Both the apparatus 300 and the apparatus 330 comprise the Bragg grating 202, the fibre core/cladding 205 and the protective coatings 206. The apparatus 300 comprises a body 302 to which the core/cladding region 205 is glued at regions 304 and 306. In this embodiment the body 302 has a substantially rectangular cross sectional area and may be formed from silicon or any other suitable rigid material.

The device 300 further comprises a flexible cover, such as a diaphragm, (not shown) which is positioned over the Bragg grating 202 and encloses recess 308 of the rigid structure 302. Alternatively, the cover may be positioned below the Bragg grating 202 and may cover the recess 308 so that an enclosed internal space is formed below the Bragg grating 202. In this case the Bragg grating 202 typically is coupled to the cover so that a movement of the cover causes a strain to the Bragg grating 202 and consequently a pressure change can be sensed.

The apparatus 330 shown in Figure 5 (b) comprises a rigid casing 332 which has a flexible cover 334. The casing 332 is hollow and the flexible cover 334 closes the casing 332 to form a hollow internal space below the Bragg grating 202. As in the previous example, the flexible cover may be a diaphragm. The optical fibre containing the Bragg grating 302 is attached to the flexible cover so that a movement of the flexible cover will cause a strain in the Bragg grating. The casing 332 typically is composed of a silicon material or of any other suitable rigid material. The flexible cover 334 typically is a thin layer that provides sufficient flexibility and is composed of silicone, another polymeric material or a suitable metallic material. In one specific embodiment the structure is formed from micro-machined silicon.

The examples of the apparatus for pressure sensing shown in Figures 2, 4 and 5 are suitable for asymmetric pressure sensing. For example, a pressure increase located only at the rigid portions of the casings 304, 303 or 332 will typically not cause a strain to the Bragg gratings 202. Figure 6 shows an apparatus for pressure sensing according to a further embodiment of the present invention which can be used for more symmetric pressure measurements.

The apparatus 400 comprises a rigid structure 402 having rigid upper and lower portions 404 and 406 and a rigid support portion 408 connecting the upper and lower portions 404 and 406. The rigid support portion is surrounded by a diaphragm 410 which is applied to the upper and lower portions 404 and 406 so that an enclosed internal space is formed. The apparatus 400 also comprises a Bragg grating 412 and a core/cladding region 414. The core/cladding region 414 is attached to the upper and lower portions 404 and 406 at positions 418 and 420. In this embodiment the core/cladding region is glued at these positions to the upper and lower portions 404 and 406 respectively, and attached to the diaphragm 410.

For example, the optical fibre with the Bragg grating 412 may be attached to the diaphragm 410 using a flexible adhesive. If a pressure in a region adjacent the diaphragm 410 changes, the diaphragm 410 will move which will cause a strain in the Bragg grating 412 and therefore the pressure change can be sensed. As the optical fibre with Bragg grating 412 is wound around the diaphragm 410 and the diaphragm 410 surrounds the support 408 so that internal space is formed between the support 408 and the diaphragm 410, a pressure change can be sensed at any position around the diaphragm 410 using the device 400. Similar to the embodiments discussed before, the Bragg grating 412 is slightly distorted into the enclosed space (the distortion is not shown in Figure 6).

The rigid portion 402, 404 and the support 408 typically is composed of silicon or of any other suitable rigid material including plastics or metallic materials. The diaphragm 410 typically is a thin layer having a thickness of the order of 0.1mm being composed of silicone, another polymeric material or a metallic material.

The hereinbefore-described apparatus for pressure sensing according to different embodiments of the present invention comprises an enclosure that defines an enclosed space and of which the diaphragm forms a part. In a variation of these embodiments, the apparatus for pressure sensing may not comprise such an enclosure and Figure 7 shows an example of such an alternative design. Figure 7 shows an apparatus for pressure 500 having an optical fibre with the Bragg grating 202 and which is attached to rigid member 504 at attachment regions 506 and 508. Diaphragm 510 distorts the Bragg grating at a normal operating temperature and separates a first region having a first pressure P_1 from a second region having a second pressure P_2. A relative change in the pressures P_1 and P_2 will move the diaphragm 510 and thereby cause a change in a force on the Bragg grating 202. As in the above-described embodiments, the diaphragm 510 and the Bragg grating 202 are positioned so that a temperature related change in optical response of the Bragg grating 202 is reduced by a temperature related change in the force on the Bragg grating. For example, the apparatus for pressure sensing 500 may be positioned across a conduit, such as a tube, for measuring a pressure caused by a flow of a fluid.

Although the invention has been described with reference to particular examples, it will be appreciated by those skilled in the art that the invention may be embodied in many other forms. For example, the apparatus for pressure sensing may comprise Bragg gratings that are positioned within the diaphragms. Further, the rigid bodies may have any suitable shape with which an enclosed internal space can be formed when a diaphragm is applied to it.

It is to be appreciated that the optical device may not necessarily be an apparatus for pressure sensing. The optical device may not comprise an enclosure that encloses a space and the moveable wall portion may not be arranged to move in response to an external pressure change. The optical device may, for example, have open ends which allow air, or any other fluid, to circulate along each side-portion of the moveable wall portion. In this instance, the temperature response of the optical device will typically be due to one or more of the thermal properties of the body, fibre and diaphragm and will not depend on any expansion of an enclosed space.

In general, the optical device may be any type of filtering, sensing or gauging device comprising a Bragg grating and wherein the moveable wall portion is arranged to reduce a temperature related change in an optical response of the Bragg grating by a temperature related change in a force on the Bragg grating. Specific examples for the optical device include spectral filters, spectral band pass filters spectral band reject (or reflection) filters, band selection filters, spectral gain filters, spectral profile filters pulse compression filters, channel dropping filters, channel blocking filters and also strain gauges.

The Claims:

1. An optical device comprising:

a light guide,

a Bragg grating incorporated into the light guide,

a moveable wall portion coupled to the Bragg grating so that a movement of the moveable wall portion causes a force that effects a change in strain of the Bragg grating and thereby effects a change in an optical period of the Bragg grating,

wherein a temperature related change in the optical period of the Bragg grating is reduced by a temperature related change in the force on the Bragg grating by the moveable wall portion.

2. The optical device of claim 1 being an apparatus for pressure sensing wherein the moveable wall portion has opposite first and second sides and is positioned so that a change in pressure at one of the sides relative to a pressure at the other side will move the moveable wall portion.

3. The optical device of claim 2 comprising an enclosure defining an enclosed space, the moveable wall portion forming a part of the enclosure and being positioned so that a change in external pressure will move the moveable wall portion.

4. The optical device of claim 3 having a normal operating temperature and pressure range at which the Bragg grating is distorted by the force caused by the moveable wall portion.

5. The optical device of claim 3 having a normal operating temperature and pressure range at which the Bragg grating is distorted into the enclosed space by the force caused by the moveable wall portion.

6. The optical device of any one of claims 3 to 5 wherein the light guide with the Bragg grating is attached to a rigid portion of the enclosure at attachment regions between which a sensing region of the Bragg grating is defined.

7. The optical device of claim 6 wherein the light guide is secured in or on the rigid portion of the enclosure so that the rigidity of the rigid portion prevents that an axial force acting on the light guide external to the enclosure affects the optical response of the Bragg grating.

8. The optical device of any one of claims 3 to 7 wherein the moveable wall portion is a diaphragm and the enclosure is arranged and the Bragg grating is positioned so that the optical response of the Bragg grating is a non-linear function of the temperature.

9. The optical device of any one of claims 3 to 8 wherein the enclosure and the Bragg grating are arranged so that the optical period of the Bragg grating does not change by more than 0.001nm if the temperature changes by ±1 degree and no more than 0.05nm if the temperature changes by ±10 degrees from a normal operating temperature of the apparatus.

10. The optical device as claimed in any one of the preceding claims wherein the light guide with the Bragg grating is in direct contact with the moveable wall portion.

11. The optical device as claimed in any one of claims 3 to 9 wherein the light guide with the Bragg grating is indirectly coupled to the moveable wall portion and the Bragg grating.

12. The optical device of any one of claims 3 to 10 wherein the Bragg grating is positioned on the diaphragm and outside the enclosure.

13. The optical device of any one of claims 3 to 10 wherein the Bragg grating is positioned within the diaphragm.

14. The optical device of any one of claims 3 to 9 wherein the Bragg grating is positioned on the diaphragm and inside the enclosure.

15. The optical device of any one of claims 3 to 14 wherein the enclosure comprises a casing that is formed from a rigid material and the movable wall portion is positioned opposite a rigid wall portion of the casing.

16. The optical device of any one of claims 3 to 14 wherein the moveable wall portion surrounds a portion of the enclosed space of the enclosure.

17. The optical device of any one of claims 3 to 14 wherein the moveable wall portion and the Bragg grating

circumferences the entire enclosed space.

18. The optical device as claimed in any one of the preceding claims comprising a series of Bragg gratings with corresponding enclosures and being arranged for distributed pressure sensing.

19. The optical device as claimed in any one of the preceding claims being arranged so that the force caused by a change in external pressure is sideway-force on the or each Bragg grating.

20. The optical device as claimed in any one of the preceding claims comprising an external catheter.

21. The optical device as claimed in any one of the preceding claims comprising a portion comprising an X-ray opaque material.

22. A method of fabricating an apparatus for pressure sensing, the method comprising:

providing a light guide having a Bragg grating,

selecting a design for a moveable wall portion, the moveable wall portion having opposite first and second sides,

positioning the moveable wall portion so that a change in pressure at one of the side relative to a pressure at the other side will move the moveable wall portion,

selecting a distortion for the or each Bragg grating, and

coupling the Bragg grating to the moveable wall portion so that the Bragg grating has the selected distortion and the movement of the moveable wall portion causes a force that effects a change in strain of the Bragg grating,

wherein the design of the moveable wall portion and the distortion of the Bragg grating are selected so that a temperature related change in optical period of the Bragg grating is reduced by a temperature related change in the force on the Bragg grating.

23. The method of claims 22 wherein the apparatus is fabricated so that the apparatus has an enclosed space and the Bragg grating is distorted into the enclosed space.

24. The method of claims 22 or 23 wherein the step of selecting a design of the moveable wall portion comprises selecting a thermal expansion coefficient of a material for forming the wall portion.

25. The method of any one of claims 22 to 24 wherein the step of selecting a design of the wall portion comprises selecting a Young's modulus for the moveable wall portion.

26. The method of any one of claims 22 to 25 wherein the step of selecting a design of the moveable wall portion comprises selecting a thermal expansion coefficient for the moveable wall portion.

27. An apparatus for pressure sensing fabricated by the method of any one of claims 22 to 26.

AMENDED CLAIMS
received by the international bureau on 13 jun 2006

distortion and the movement of the moveable wall portion causes a force that effects a change in strain of the Bragg grating,

wherein the design of the moveable wall portion and the distortion of the Bragg grating are selected so that a temperature related change in optical period of the Bragg grating is reduced by a temperature related change in the force on the Bragg grating.

23. The method of claims 22 wherein the apparatus is fabricated so that the apparatus has an enclosed space and the Bragg grating is distorted into the enclosed space.

24. The method of claims 22 or 23 wherein the step of selecting a design of the moveable wall portion comprises selecting a thermal expansion coefficient of a material for forming the wall portion.

25. The method of any one of claims 22 to 24 wherein the step of selecting a design of the wall portion comprises selecting a Young's modulus for the moveable wall portion.

26. The method of any one of claims 22 to 25 wherein the step of selecting a design of the moveable wall portion comprises selecting a thermal expansion coefficient for the moveable wall portion.

27. An apparatus for pressure sensing fabricated by the method of any one of claims 22 to 26.

28. A method of measuring a pressure in an in-vivo environment, the method comprising:

inserting an apparatus for pressure sensing into a body, the apparatus comprising a light guide and a Bragg grating incorporated into the light guide,

exposing the apparatus to a pressure in the in-vivo environment so that the pressure causes a force on the Bragg grating which changes a strain of the Bragg grating and thereby changes an optical period of the Bragg grating,

reducing a temperature related change in the optical period of the Bragg grating by a temperature related change in the force on the Bragg grating.

guiding light to and from the Bragg grating and receiving a response from the Bragg grating.

29. The method of claim 28 comprising the step of converting optical data into pressure data.

30. A method of measuring a muscular pressure in an in-vivo environment comprising the method as claimed in claim 28 or 29.

31. A method of measuring a muscular pressure in the oesophagus comprising the method as claimed in claim 28 or 29.

32. A method of measuring a pressure in an in-vivo environment using the optical device as claimed in any one of claims 1 to 21.

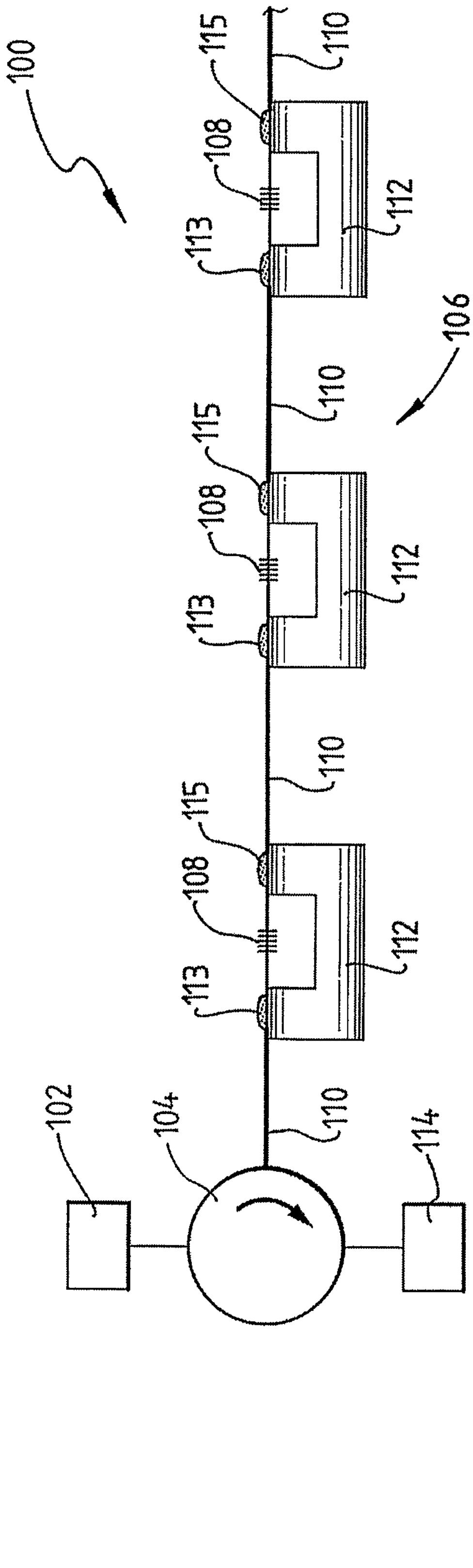
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Fig. 1(a)

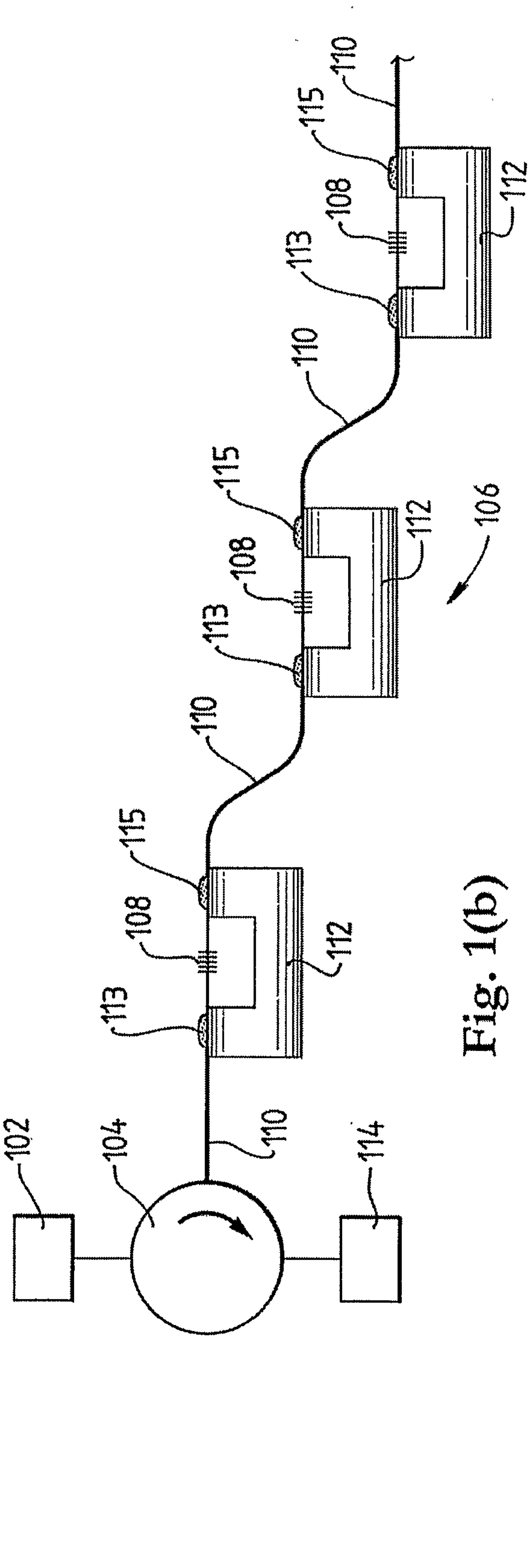
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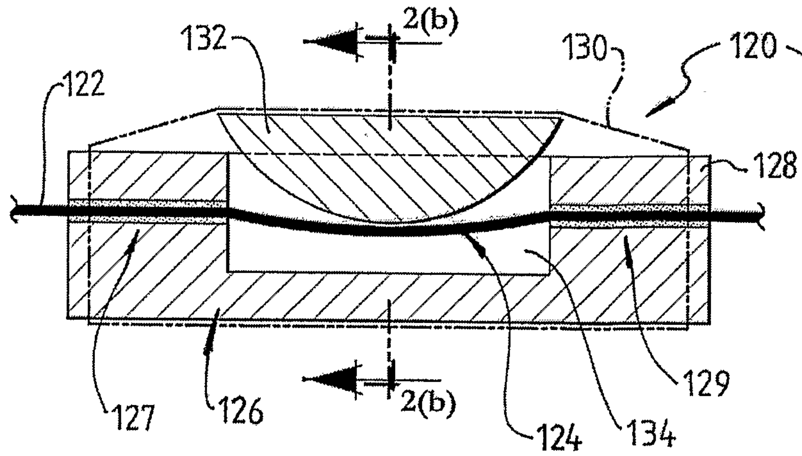
Fig. 1(b)



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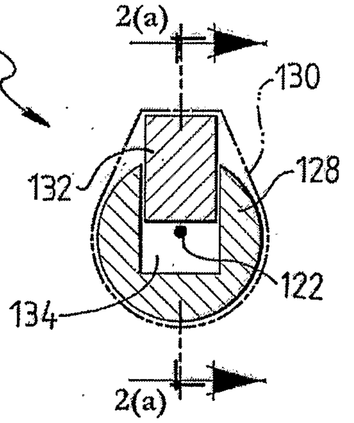

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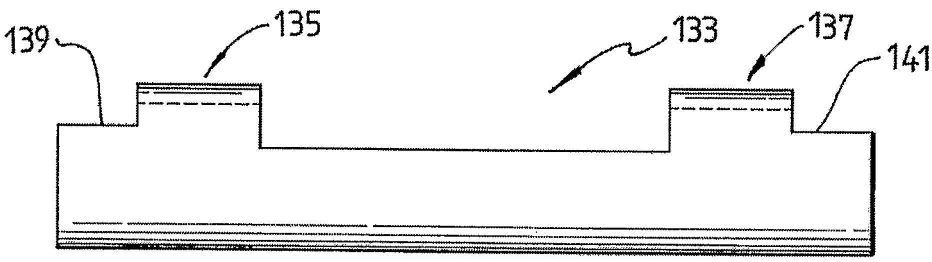

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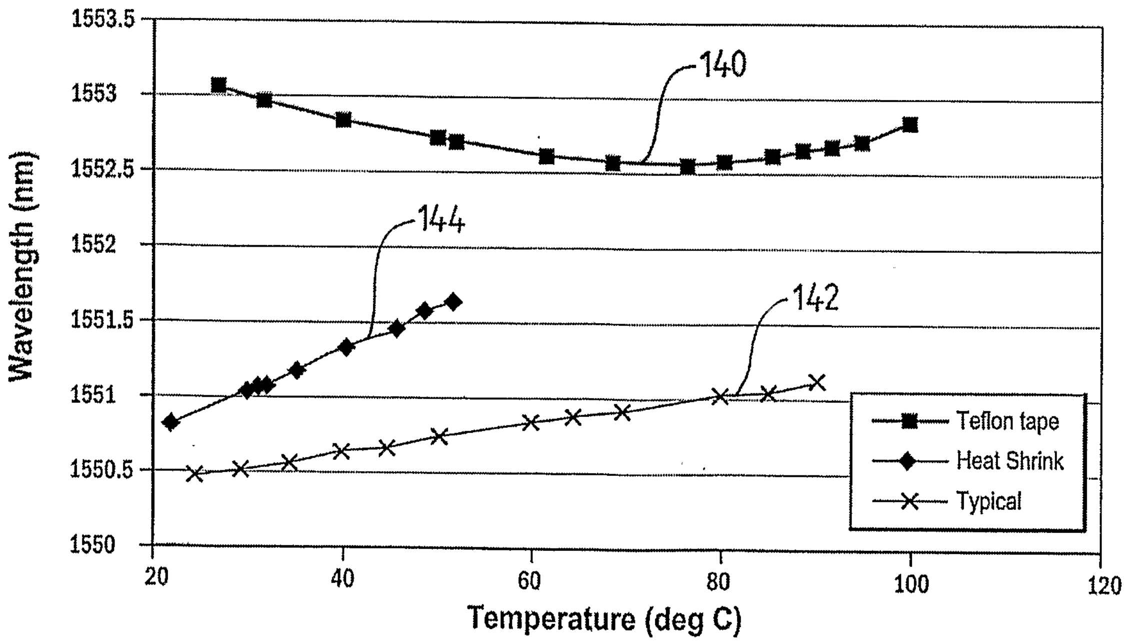

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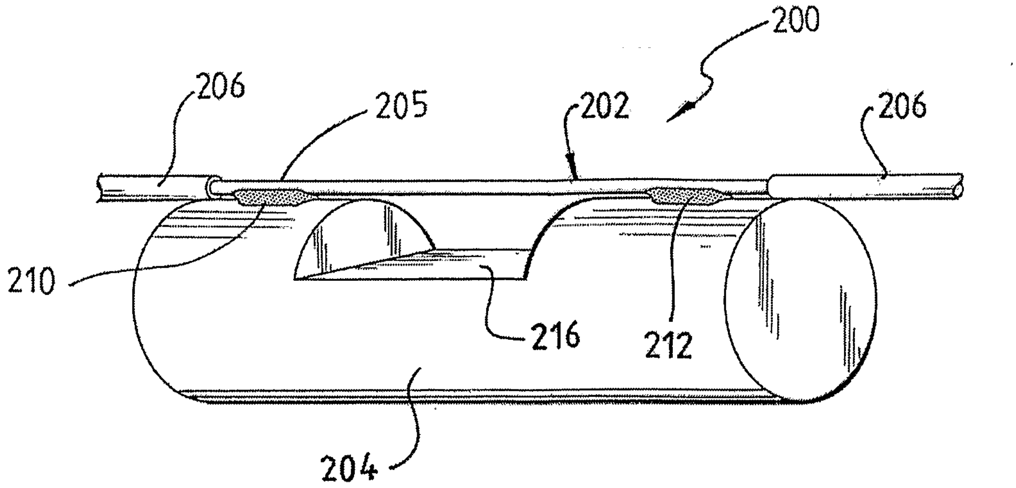

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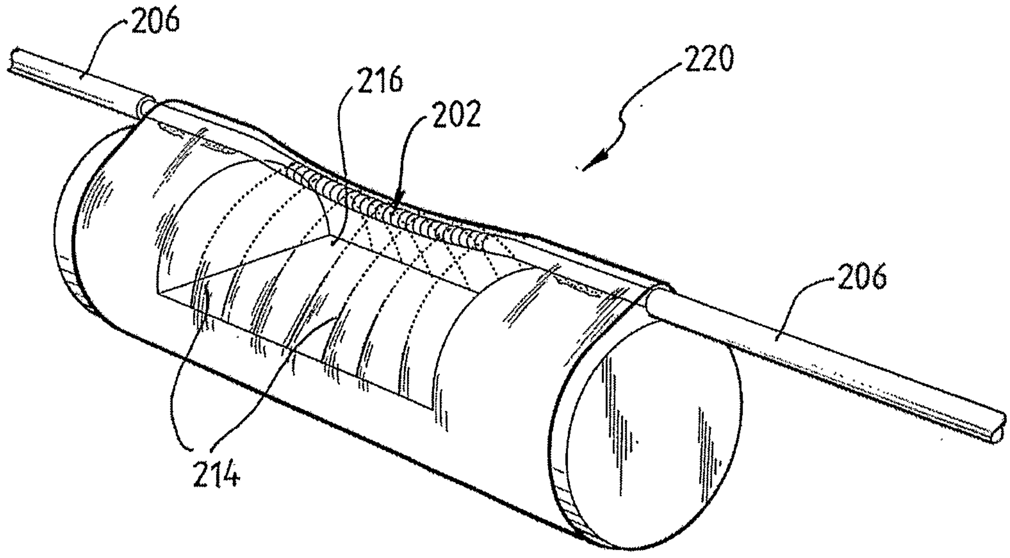
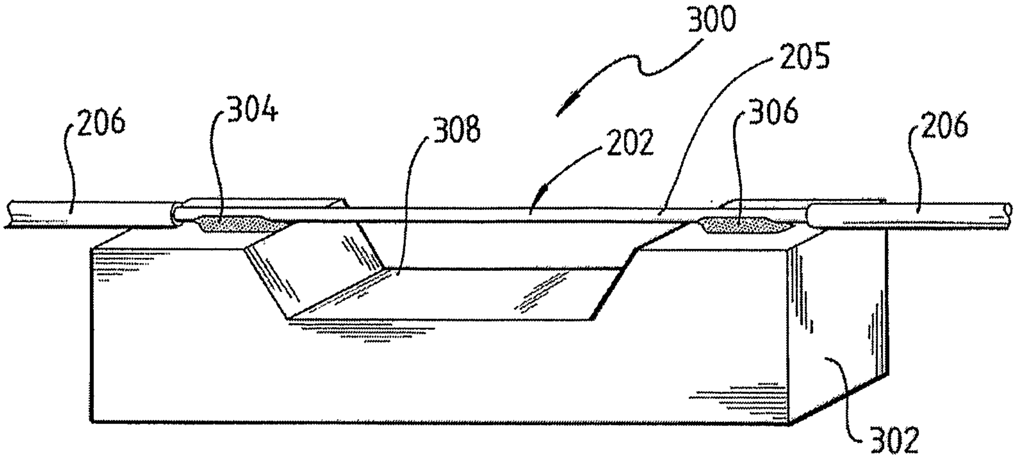


Fig. 4(b)



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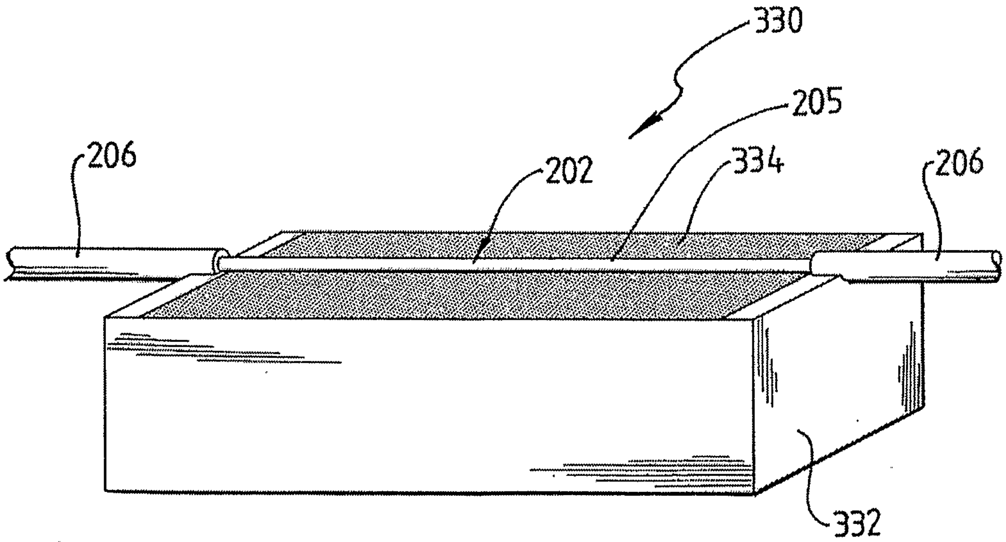

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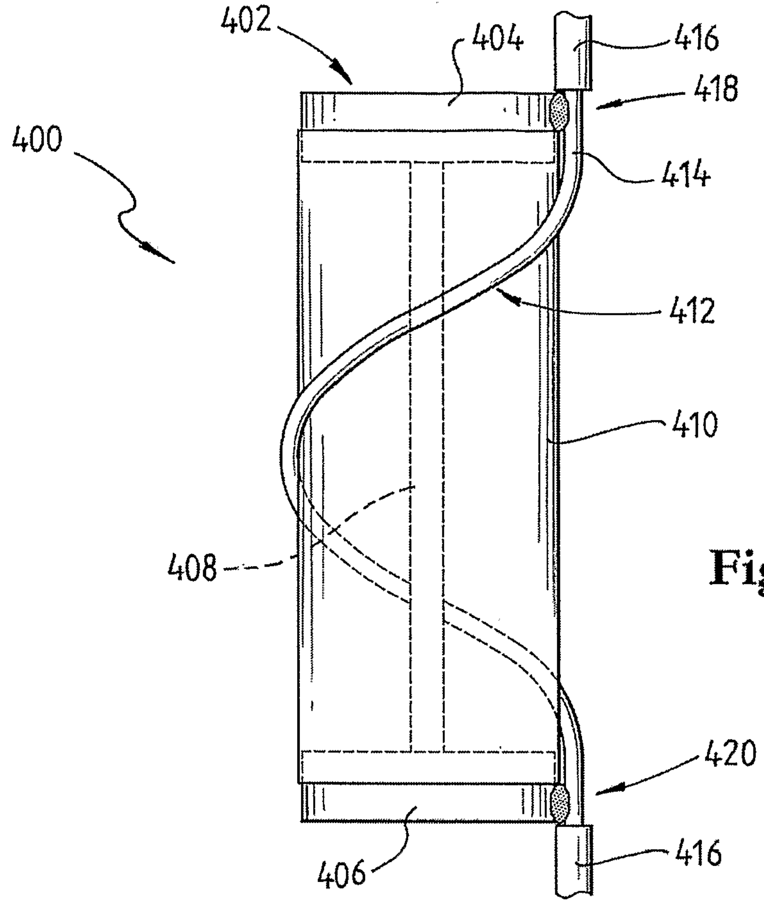
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Fig. 6

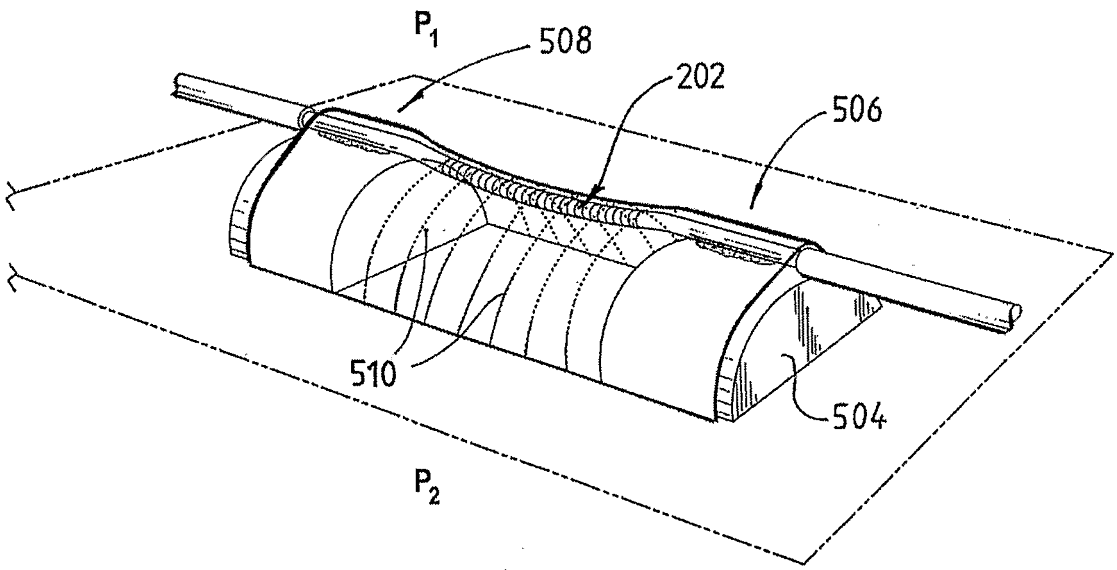
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Fig. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2006/000309

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

G02B 27/44 (2006.01) *G01D 5/353* (2006.01) *G01L 1/24* (2006.01)
A61B 5/00 (2006.01) *G01L 11/02* (2006.01)

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)

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)
DWPI and keywords: pressure, sensor, distribute, Bragg, grating, moveable, flexible, deform, wall, enclosure, member, diaphragm, termperature, optical period, force, and other similar terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6181851 B1 (PAN ET AL) 30 January 2001 See entire document	1-7 10, 16, 17
A	US 6218661 B1 (SCHROEDER ET AL) 17 April 2001 See entire document	
A	US 2004/0114849 A1 (SHAH, JAGDISH ET AL) 17 June 2004 See entire document	

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"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)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 April 2006	20 APR 2006

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2006/000309

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2000/033048 A2 (CIDRA CORPORATION) 8 June 2000 See entire document	
A	Patent Abstracts of Japan, JP 2000-097786 A (FURUKAWA ELECTRIC CO LTD:THE) 7 April 2000 See Abstract	
A	WO 2004/007127 A2 (COMMISSARIAT A L'ENERGIE ATOMIQUE) 22 January 2004 See Abstract	
A	US 2004/0237648 A1 (JONES ET AL) 2 December 2004 See entire document	
A	WO 2002/019903 A1 (OPTOMED AS) 14 March 2002 See entire document	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU2006/000309

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	6181851	NONE					
US	6218661	AU	43361/97	AU	64287/99	AU	82883/98
		CA	2258640	CA	2295919	CN	1230253
		CN	1269881	EP	0923703	EP	0995091
		ID	26513	NO	991026	NO	20000039
		US	5828059	US	5841131	WO	0025103
		WO	9810242	WO	9902953		
US	20040114849	GB	2396409	US	6898339		
WO	0033048	AU	29588/00	US	6278811		
JP	2000097786	NONE					
WO	20040237648	NONE					
WO	2004007127	AU	2003260657	EP	1519806	FR	2841812
		FR	2841813	US	2005232568		
WO	0219903	AU	86056/01	GB	2371359	US	7003184
		US	2002041724				

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX

专利名称(译)	温度补偿布拉格光栅光学器件		
公开(公告)号	EP1859312A1	公开(公告)日	2007-11-28
申请号	EP2006704982	申请日	2006-03-09
[标]申请(专利权)人(译)	联邦科学和工业研究组织		
申请(专利权)人(译)	联邦科学与工业研究组织		
当前申请(专利权)人(译)	联邦科学与工业研究组织		
[标]发明人	ARKWRIGHT JOHN WILLIAM DOE SIMON NICHOLAS TYAGI VINAY KUMAR PRESTON EDWARD WILLIAM		
发明人	ARKWRIGHT, JOHN WILLIAM DOE, SIMON NICHOLAS TYAGI, VINAY KUMAR PRESTON, EDWARD WILLIAM		
IPC分类号	G02B27/44 G01D5/353 G01L1/24 A61B5/00 G01L11/02		
CPC分类号	G01L1/246 A61B5/0215 G01D5/35303 G02B6/2932 G02B6/29322 G02B7/008		
代理机构(译)	博伊斯康纳尔		
优先权	2005901143 2005-03-10 AU 2005906109 2005-11-04 AU		
外部链接	Espacenet		

摘要(译)

一种装置，包括结合有布拉格光栅的光导（110）。该装置还包括可移动的壁部分，该可移动的壁部分耦合到布拉格光栅（108），使得壁部分的运动产生影响布拉格光栅的应变变化的力，从而实现光学周期的变化。布拉格光栅。通过可移动壁部分对布拉格光栅上的力的温度相关变化减小了布拉格光栅的光学周期中与温度相关的变化。