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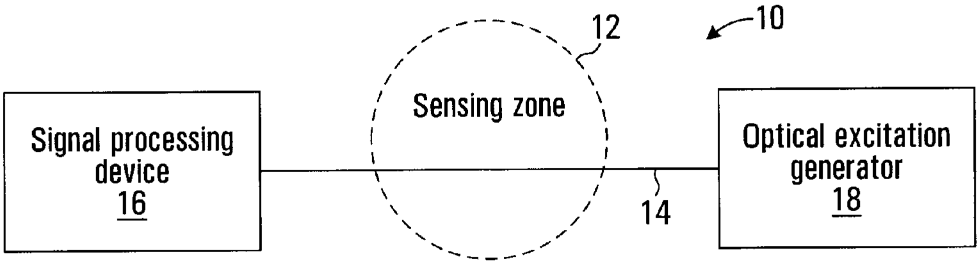
(54) Title: OPTICAL DEVICE FOR MEASURING A PHYSICAL PARAMETER IN A HYDROGEN CONTAMINATED SENSING ZONE



(57) Abstract: A signal processing apparatus which has an input for receiving a signal conveying a response from first and second optical components to an optical excitation. The first and second optical components are in an optical sensor which is intended to be placed in a sensing zone. The sensing zone contains hydrogen susceptible to migrate into the optical sensor. The signal processing apparatus has a processing entity for processing the response from the first and second optical components to derive information on hydrogen concentration in the optical sensor.

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TITLE: Optical device for measuring a physical parameter in a hydrogen contaminated sensing zone

FIELD OF THE INVENTION

The invention relates to optical measuring devices and in particular to a measuring device, components thereof and methods for measurement for applications where the sensing zone in which the measurement is to be made contains hydrogen that can potentially contaminate optical components of the optical measuring device.

BACKGROUND OF THE INVENTION

The effects of hydrogen diffusion into optical fibers have been studied for more than a decade. Four principal aspects have been the objects of these studies: enhancing the photosensitivity of optical fibers, Bragg wavelength shift due to an increase of the effective index of optical fiber, absorption losses increase and hydrogen sensing.

More specifically, the presence of hydrogen molecules in the optical fiber changes its effective refractive index (n_{ef}). When a Bragg grating is present in the optical fiber, the resulting reflected Bragg wavelength (λ_B) as described by the Bragg condition equation is affected by the refractive index change:

$$\lambda_B = 2\, n_{eff}\, \Lambda \qquad (1)$$

where Λ is the period between the fringes of different refractive indexes.

Another effect of the presence of molecular hydrogen into an optical fiber is the increased attenuation of the light energy traveling through it, via molecular absorption. This phenomenon has an impact on fiber optics based monitoring systems for oil and gas extraction where pressure, temperature and environmental hydrogen concentration are usually quite high.

It is known to use either Bragg wavelength shift or absorption losses increase due to the presence of molecular hydrogen in the core of an optical fiber to monitor the concentration of hydrogen in the environment, or in other substances that would chemically react to create hydrogen. This type of sensors can have a very slow dynamic reactive time because it is limited by the diffusion rate of hydrogen through the glass of the optical fiber until it reaches the core of the fiber. Typically it takes a month to reach 97.3% of the equilibrium concentration of hydrogen for a standard 125 microns diameter fiber at 20°C. For that reason, most hydrogen sensors based on fiber Bragg gratings use a hydrogen-reactive coating, such as a palladium-based coating, that swells by absorbing hydrogen, and so, strain the fiber segment containing the Bragg grating increasing the refractive indexes fringes (Λ).

There is a need in the industry to provide optical measuring devices that can operate in sensing zones containing hydrogen, that are of simple construction, are reliable and provide accurate measurements results.

SUMMARY OF THE INVENTION

As embodied and broadly described herein the invention provides a signal processing apparatus which has an input for receiving a signal conveying a response from first and second optical components to an optical excitation. The first and second optical components are in an optical sensor which is intended to be placed in a sensing zone. The sensing zone contains hydrogen susceptible to migrate into the optical sensor. The signal processing apparatus has a processing entity for processing the response from the first and second optical components to derive information on hydrogen concentration in the optical sensor.

As embodied and described herein the invention also provides a measurement apparatus having an optical sensor for use in a sensing zone containing hydrogen susceptible to migrate into the optical sensor. The optical sensor has first and second optical components for generating a response to optical excitation impressed in the optical sensor. The measurement apparatus has an input for receiving the response generated by the first and second optical components and a processing entity for processing the response to derive information on hydrogen concentration in the optical sensor.

As embodied and described herein the invention also provides an apparatus for measuring a physical parameter. The apparatus has an optical sensor for exposure to the physical parameter, the optical sensor capable of producing a response dependent on the intensity of the physical parameter acting on the optical sensor. The optical sensor is susceptible to contamination by hydrogen potentially present in the vicinity of the optical sensor. The apparatus also has a processing entity in communication with the optical sensor for processing the response to derive a measure of the physical parameter intensity corrected for hydrogen contamination. The processing operation including determining from information contained in the response a degree of attenuation an optical signal manifests in the optical sensor, in at least at two different ranges of wavelengths of light.

As embodied and broadly described herein the invention also provides a method for measuring a physical parameter in a sensing zone, the method comprising placing an optical sensor in the sensing zone, the optical sensor including a plurality of optical components responsive to the intensity of the physical parameter acting on the optical sensor. The optical sensor is susceptible to contamination by hydrogen potentially present in the sensing zone which alters the response manifested by the optical components to the physical parameter. The method also includes introducing an optical excitation in the optical sensor and observing the response of the optical components to the optical excitation, the optical components responding to different ranges of wavelengths of light in the optical excitation. The method also includes processing the response of the optical components to derive a measure of the physical parameter intensity corrected for hydrogen contamination.

As embodied and broadly described herein, the invention also provides a method to derive information on hydrogen concentration in an optical sensor located in a sensing zone containing hydrogen susceptible to migrate into the optical sensor. The method includes receiving a signal conveying a response from first and second optical components of the optical sensor to an optical excitation and processing the response from the first and second optical components to derive information on hydrogen concentration in the optical sensor.

As embodied and broadly described herein, the invention also provides a method for measuring hydrogen concentration in an optical sensor. The method includes receiving a signal conveying a response from the optical sensor to an optical excitation and processing the response to derive a measure of the hydrogen concentration in the optical sensor. The processing operation includes determining from information contained in the response a degree of attenuation an optical signal manifests in the optical sensor, in at least at two different ranges of wavelengths of light.

As embodied and broadly described herein the invention also provides an apparatus for measuring temperature in a well of an oil extraction installation. The apparatus has an optical sensor for placement in the well which contains hydrogen susceptible to migrate into the optical sensor. The apparatus also has a signal processing device for processing an optical response of the optical sensor and derive from the optical response a temperature measurement in the well corrected for effects of hydrogen migration into the optical sensor.

As embodied and broadly described herein the invention also provides a method for measuring temperature in a well of an oil extraction installation, the method comprising the step of receiving an optical response from an optical sensor placed in the well which contains hydrogen susceptible to migrate into the optical sensor. The method also includes performing signal processing on information conveyed in the optical response and deriving from the information a temperature measurement in the well corrected for effects of hydrogen migration into the optical sensor.

As embodied and broadly described herein the invention further includes an optical sensor for measuring temperature in a well of an oil extraction installation, the well contains hydrogen susceptible to migrate into the optical sensor. The optical sensor has a first optical component and a second optical component and a common optical path containing the first optical component and the second optical component. The first and second optical components are capable of generating an optical response to an optical excitation conveying information from which can be derived a temperature measurement corrected for effects of hydrogen migration into the optical sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

A detailed description of examples of implementation of the present invention is provided hereinbelow with reference to the following drawings, in which:

Figure 1 is block diagram of a measuring apparatus according to a non-limiting example of implementation of the invention;

Figure 2 is an enlarged view of the optical sensor of the apparatus shown in Figure 1;

Figure 3 is block diagram of the signal processing device of the measurement apparatus shown in Figure 1;

Figure 4 is a diagram of a measuring apparatus according to a variant;

Figure 5 is a flowchart of an iterative algorithm executed by the signal processing device shown in Figure 3 to calculate the temperature and hydrogen concentration in the optical sensor using peak wavelength shift and the difference in absorbed light of two proximal fiber gratings at different wavelength ranges;

Figure 6 is a flowchart of the iterative algorithm according to a variant;

Figure 7 is a graph illustrating the general profile of the hydrogen absorption spectrum in the telecommunication C-band window;

Figure 8 is a graph showing the general profile of the hydrogen absorption spectrum in the telecommunication C-band window, normalized using the absorption at 1552.5 nm.

In the drawings, embodiments of the invention are illustrated by way of example. It is to be expressly understood that the description and drawings are only for purposes of illustration and as an aid to understanding, and are not intended to be a definition of the limits of the invention.

DETAILED DESCRIPTION

Figure 1 shows a measurement apparatus 10 that measures the intensity of a physical parameter, such as temperature, pressure of strain. The measurement is performed in a sensing zone 12. Generally, the measurement apparatus 10 has an optical sensor 14 which is located in the sensing zone 12, a signal processing device 16 which performs an analysis of the optical response generated by the optical sensor 14, and an optical excitation generator 18 that injects into the optical sensor 14 an optical excitation.

The sensing zone 12 is the area where the measurement is to be made. In this specific example of implementation, the sensing zone 12 is susceptible to contain gaseous hydrogen. The hydrogen can migrate into the optical sensor and affect the way the sensor responds to the physical parameter. This will, in turn, produce an erroneous reading of the intensity of the physical parameter at the signal processing device 16 unless the measurement is corrected to take into account the hydrogen concentration. Specific applications where the measurement apparatus 10 can be used include oil and gas exploration/exploitation where the need exists for optical sensors that can reliably function in areas that often contain hydrogen gas.

Figure 2 shows in greater detail the optical sensor 14. The optical sensor 14 has a continuous length of optical fiber 20. The optical fiber 20 has a core. Hydrogen in the sensing zone 12 can migrate into the core of the optical fiber 20 which raises the index of refraction of the hydrogen containing section of the core. The optical sensor 14 has two optical components 22, 24 that respond to different ranges of wavelengths of light. In the example shown in the drawings, the optical components include gratings, such as straight Bragg gratings (the fringes are perpendicular to the optical fiber axis), a tilted Bragg grating or long period gratings. The optical components may also include Fabri-Perot or Mach-Zehnder type components. The optical components 22, 24 manifest in response to a change in intensity of the physical parameter acting on the optical components 22, 24, a shift in the range of wavelength filtered out from the optical excitation. For instance when the physical parameter is temperature, a rise or a drop in the temperature of the optical sensor 14 will cause the response of the optical components 22, 24 to change. This change is detected by the signal processing device 16 and used to obtain a measurement of the intensity of the physical parameter.

In use, the optical excitation generator 18 generates light which is injected into the optical fiber length that leads to the optical sensor 14. The optical excitation reaches the fiber gratings 22, 24 which filter out from the optical excitation two distinct wavelength ranges. Specifically, the wavelengths in the ranges of wavelengths of light to which the fiber gratings 22, 24 respond are reflected back toward the optical excitation generator such that the optical excitation that reaches the signal processing device 16 is lacking the wavelengths in those ranges. The signal processing device 16 uses the information it receives from the optical sensor 14 to derive the intensity of the physical parameter acting on the optical sensor 14 in the sensing zone 12, corrected for hydrogen concentration in the optical sensor. As indicated previously, the physical parameter can be the temperature, pressure or mechanical strain acting on the optical sensor 14. In the case of mechanical strain or pressure, there may be a necessity to mount the optical sensor 14 on a transducer structure (not shown in the drawings) that is directly exposed to pressure or mechanical strain and communicates this pressure or mechanical strain directly to the optical sensor 14. Such transducer structures are known in the art and do not need to be discussed here in greater details.

Note that while the specification discusses the fiber gratings 22, 24 as being responsive to respective ranges of wavelength, in practice those ranges are quite narrow, since in most practical applications the fiber gratings 22, 24 are designed to be as selective as possible. For the purposes of performing signal analysis on the fiber gratings 22, 24 responses, where a mathematical representation of a range of wavelengths may be overly complex, it is acceptable to represent the response of a fiber grating by a single wavelength, such as the peak wavelength in the range.

The signal processing device extracts from the response from the optical sensor 14 the wavelength ranges that have been filtered out by the gratings 22, 24 and also the degree at which the optical excitation has been attenuated in the optical sensor. The degree of optical excitation attenuation is due largely to the hydrogen concentration in the core of the optical sensor 14. These two elements of information can then be used to determine the hydrogen concentration in the core of the optical sensor 14, the temperature of the optical sensor 14, as well as the intensity of the physical parameter acting on the optical sensor 14 (other than temperature).

Techniques to determine the degree of attenuation of an optical signal in an optical fiber are generally known and will not be described in detail. Suffice it to say that a determination of the degree of attenuation can be made by comparing the amount of power received by the signal processing device 16 to the amount of power injected by the optical excitation generator 18. In instances where a direct measure of the amount of power injected by the optical excitation generator 18 is not readily available, a computation based on the nominal amount of power produced by the optical excitation generator can be used as a basis for calculating the degree of attenuation.

Figure 3 provides a block diagram of the signal processing device 16. The signal processing device 16 is based on a computer platform that enables to perform digital signal processing on the response received from the optical sensor 14 such as to derive the information desired. More specifically, the signal processing device 16 includes in input interface 26 that is coupled to the optical fiber length leading directly to the optical sensor 14. The input interface 26 will convert the signal into an electric digital signal, including performing appropriate filtering. The digital signal is then impressed on the data bus 27 that establishes a communication path between a processor 28 and a memory device 30. The processor 28 executes program code that defines a mathematical model establishing a relationship between the information that is available in the response received from the optical sensor 14 and the information that is sought, namely the hydrogen concentration, temperature and intensity of a physical parameter, other than temperature.

The signal processing device 16 also has an output interface 32 that allows communicating the result of the mathematical processing to an external entity. The external entity can be a human operator or a piece of equipment that uses the information generated by the signal processing device 16 for specific purposes.

Molecular hydrogen absorbs photons according to their wavelength; Figure 7 shows a typical hydrogen absorption spectrum over the C-band telecommunication window. The level of losses depends on the temperature (T), the molar concentration of hydrogen in the core ($[H_2]$) and the light path length (L), but the ratio of absorption is constant between two wavelengths. The absorption loss due the presence of hydrogen in the core of an optical fiber can be described by a relation of the following form:

$$H_2 \text{ loss } (\lambda, T) = A\, f\,(\lambda/\lambda_{ref})\, g\,(T)\, [H_2]\, L \qquad (2)$$

where λ is the specific wavelength at which the absorption is calculated, $g\,(T)$ is the increasing molecular absorption function with temperature of Arrhenius type, A is the absorption at the reference wavelength of one unitary concentration of hydrogen for one unity of length at the Arrhenius reference temperature and $f\,(\lambda/\lambda_{ref})$ is the function describing the ratio of absorption with wavelength normalized against a specific wavelength. Such a function, $f\,(\lambda/\lambda_{ref})$, is illustrated in Figure 8, where absorption at 1552.5 nm is used as the normalization reference; in this case, the function has been represented using splines to approximate the relationship.

The presence of hydrogen in the optical sensor 14 also raises its effective index, shifting linearly the reflected Bragg wavelength:

$$\Delta\lambda_B = B\,[H2] \qquad (3)$$

The temperature also raises effective index of the optical fiber, shifting independently and also linearly the reflected Bragg wavelength:

$$\Delta\lambda_B = B\,[H2] + C\,(T - T_{ref}) \qquad (4)$$

By using two optical components 22, 24 in the form of fiber gratings at very close proximity to one another, one can assume that they are for all practical purposes at the same location, so the temperature, light path length and hydrogen concentration in the core of the optical sensor 14 are the same for both optical components 22, 24. The difference in absorption losses is then given by:

$$H_2\,\text{loss}\,(\lambda_1, T) - H_2\,\text{loss}\,(\lambda_2, T) = \{A\,g\,(T)\,[H_2]\,L\}\,\{f\,(\lambda_1/\lambda_{ref}) - f\,(\lambda_2/\lambda_{ref})\} \qquad (5)$$

The signal processing device 16 can determine using known signal processing techniques the wavelength ranges to which the fiber gratings 22, 24 respond and the degree of attenuation the optical excitation has been subjected to by the optical sensor 14. This can therefore yield $\{H_2\,\text{loss}\,(\lambda_1, T) - H_2\,\text{loss}\,(\lambda_2, T)\}$, λ_1 and λ_2. The model characterization supplies all the other parameters except for the temperature and hydrogen concentration. Using equations (4) and (5), it is possible to solve the mathematical system using standard methods and obtain the values of hydrogen concentration and temperature in the core of the optical sensor 14 where the fiber gratings 22, 24 are located.

Several mathematical methods can be used to resolve these equations. Figure 5 is an example of an iterative algorithm that is executed by the processor 28. The algorithm is a convergent iterative scheme that computes the hydrogen concentration and the temperature. The process begins at step 34 which assumes a temperature value. Step 36 uses then equation (5) to calculate the hydrogen concentration in the core of the optical sensor 14. Once the hydrogen concentration is known, the responses of the gratings 22, 24 are corrected for the hydrogen concentration effect, at step 38. Step 40 then computes anew the temperature from the remaining peak wavelength shifts. Step 42 compares the assumed temperature at step 34 to the calculated one; if the difference is too large (step 42), the algorithm is run one more time, the new iteration using the calculated temperature as the estimation. Since the mathematical system is naturally convergent, this process will result into a solution after a number of iterations. The solution provides both a temperature and hydrogen concentration values in the core of the optical sensor 14.

Note that since the mathematical system has two unknowns, the hydrogen concentration and the temperature, and three equations are available, equation (5) and one equation (4) for each fiber grating wavelength shift, the fiber gratings wavelength shifts can be used to measure another parameter or measurand (M) such as the intensity of the physical parameter acting on the optical sensor 14, other than temperature for which a result is already available. As indicated earlier, strain on the optical sensor causes an increase of the period of the fringes of refractive index (Λ), and so shifts the Bragg wavelength linearly according to equation (1) and independently of hydrogen or thermal effects. Using transducer structures as discussed above, several measurands, such as force, pressure, can be converted into strain of the fiber. Then:

$$\Delta\lambda_B = B\,[H2] + C\,(T-T_{ref}) + D\,(M-M_{ref}) \qquad (6)$$

Figure 6 is a slightly modified iterative algorithm to enable the fiber gratings 22, 24 to measure a third independent measurand, such as the intensity of pressure or mechanical strain. The only difference with the previous algorithm is that the temperature calculation is changed by solving a two parameters matrix. It should be expressly noted that the algorithms discussed earlier are only examples of methods to obtain the information desired from the responses from the gratings 22, 24 and the invention should not be limited to those methods since other techniques can also be used without departing from the spirit of the invention.

Figure 4 shows a variant of the optical sensor discussed in Figure 2. In this example, the optical sensor has two optical fibers, one fiber containing a pair of closely spaced Bragg gratings that are used primarily to compute the hydrogen concentration in the sensing zone. Another Bragg grating, located in a separate optical fiber that is adjacent the pair of gratings, is used to measure the intensity of the physical parameter acting on the optical sensor in the sensing zone. The response of the single Bragg grating can be corrected to compensate for the hydrogen concentration computed based on the response obtained from the pair of Bragg gratings.

The above examples of implementation of the invention have all been discussed in the context of systems using optical responses based on signal transmission through optical components. In other words, the information conveyed in the response is carried in the part of the optical excitation passing through the optical components. It is also possible to use systems based on signal reflection where the response resides in the portion of the optical excitation that is reflected instead of being transmitted.

The various embodiments discussed earlier can be used for different practical applications. One example is the field of oil/gas exploration where it is often required to obtain temperature measurements in deep wells that contain a sufficient concentration of hydrogen gas, which as discussed earlier can migrate into the optical sensor and affect its index of refraction.

Specifically, the extraction of oil from oil sands requires the injection of steam into a well that softens the bitumen sufficiently allowing it to flow to the surface via a collection conduit. For operational reasons, it is necessary to monitor the temperature inside the steam well with reasonable accuracy. Temperature measuring devices constructed according to the principles of the present invention have been found satisfactory. Specifically, since those devices are optical they do not require electrical energy to operate and, therefore, do not create a risk of explosion due to the high concentration of gases capable of igniting and burning. In addition, they measuring devices can correct the raw measurements for the effects of hydrogen diffusion and thus produce accurate results.

Although various embodiments have been illustrated, this was for the purpose of describing, but not limiting, the invention. Various modifications will become apparent to those skilled in the art and are within the scope of this invention, which is defined more particularly by the attached claims.

CLAIMS:

1) Signal processing apparatus, comprising:
   a) an input for receiving a signal conveying a response from first and second optical components of an optical sensor to an optical excitation, said optical sensor intended for use in a sensing zone containing hydrogen susceptible of contaminating the optical sensor by hydrogen diffusion in the optical sensor;
   b) a processing entity for processing the response from the first and second optical components to derive information on hydrogen concentration in the optical sensor.

2) A signal processing apparatus as defined in claim 1, wherein the optical sensor defines an optical path, the first optical component and the second optical component being located in the optical path.

3) A signal processing apparatus as defined in claim 2, wherein the first optical component and the second optical component receive the optical excitation via the optical path.

4) A signal processing apparatus as defined in claim 3, wherein the first optical component and the second optical component convey the response via the optical path.

5) A signal processing apparatus as defined in claim 4, wherein at least a portion of the optical path is defined by a continuous length of optical fiber, the first optical component and the second optical component being located in the continuous length of optical fiber.

6) A signal processing apparatus as defined in claim 5, wherein the first optical component and the second optical component filter out from the optical excitation different ranges of wavelengths of light.

7) A signal processing apparatus as defined in claim 6, wherein the first and second optical components are gratings.

8) A signal processing apparatus as defined in claim 7, wherein the gratings manifest in response to a change in intensity of a physical parameter acting on the gratings, a shift in the ranges of wavelengths filtered out from the optical excitation.

9) A signal processing apparatus as defined in claim 8, wherein the physical parameter is selected from the group consisting of temperature, pressure and strain.

10)A signal processing apparatus as defined in claim 9, wherein the gratings are selected in the group consisting of Bragg gratings and long period gratings.

11)A signal processing apparatus as defined in claim 5, wherein the response conveys

a) information on a range of wavelengths of light in the optical excitation filtered out by the first optical component;
b) information on a range of wavelengths of light in the optical excitation filtered out by the second optical component;
c) information on attenuation of the optical excitation in the optical sensor occurring at the range of wavelengths filtered out by the first optical component;
d) information on attenuation of the optical excitation in the optical sensor occurring at the range of wavelengths filtered out by the second optical component.

12)A signal processing apparatus as defined in claim 11, wherein said processing entity using the information a, b, c and d as factors in deriving information on hydrogen concentration in the optical sensor.

13) A signal processing apparatus as defined in claim 11, wherein said processing entity using the information a, b, c and d as factors in deriving information on temperature in the sensing zone.

14) A signal processing apparatus as defined in claim 12, wherein said processing entity includes software code to process the information a, b, c and d as factors in deriving information on hydrogen concentration in the optical sensor.

15) A signal processing apparatus as defined in claim 14, wherein said software code embodies a mathematical model establishing a relationship between the hydrogen concentration in the optical sensor, the temperature in the sensing zone and the information c and d.

16) Measurement apparatus, comprising:

a) an optical sensor for use in a sensing zone containing hydrogen susceptible to migrate into said optical sensor, said optical sensor having first and second optical components for generating a response to optical excitation impressed in said optical sensor;

b) an input for receiving the response generated by said first and said second optical components;

c) a processing entity for processing the response to derive information on hydrogen concentration in the optical sensor.

17) Measurement apparatus as defined in claim 16, wherein said optical sensor defines an optical path, said first optical component and said second optical component being located in said optical path.

18) Measurement apparatus as defined in claim 17, wherein said first optical component and said second optical component convey the respective responses via said optical path.

19) Measurement apparatus as defined in claim 17, wherein at least a portion of said optical path is defined by a length of optical fiber, said first optical

component and said second optical component being located in said length of optical fiber.

20) Measurement apparatus as defined in claim 18, wherein said first optical component and said second optical component filter out from the optical excitation different ranges of wavelengths of light.

21) Measurement apparatus as defined in claim 20, wherein said first and second optical components include gratings.

22) Measurement apparatus as defined in claim 20, wherein the gratings manifest in response to a change in intensity of a physical parameter acting on the gratings, a shift in the range of wavelengths filtered out from the optical excitation.

23) Measurement apparatus as defined in claim 22, wherein the physical parameter is selected from the group consisting of temperature, pressure and strain.

24) Measurement apparatus as defined in claim 23, wherein said gratings are selected in the group consisting of Bragg gratings and long period gratings.

25) Measurement apparatus as defined in claim 22, wherein said response conveys:

a) information on a range of wavelengths of light in the optical excitation filtered out by said first optical component;
b) information on a range of wavelengths of light in the optical excitation filtered out by said second optical component;
c) information on attenuation of the optical excitation in the optical sensor occurring at the range of wavelengths filtered out by said first optical component;
d) information on attenuation of the optical excitation in the optical sensor occurring at the range of wavelengths filtered out by said second optical component.

26) Measurement apparatus as defined in claim 25, wherein said processing entity using the information a, b, c and d as factors in deriving information on hydrogen concentration in said optical sensor.

27) Measurement apparatus as defined in claim 25, wherein said processing entity using the information a, b, c and d as factors in deriving information on temperature of the optical sensor.

28) Measurement apparatus as defined in claim 25, wherein said processing entity includes software code to process the information a, b, c and d as factors in deriving information on hydrogen concentration in the optical sensor.

29) Measurement apparatus as defined in claim 28, wherein said software code embodies a mathematical model establishing a relationship between the hydrogen concentration in the optical sensor, the temperature in the sensing zone and the information c and d.

30) An apparatus for measuring a physical parameter, said apparatus comprising:

a) an optical sensor for exposure to the physical parameter, said optical sensor capable to produce a response dependent on the intensity of the physical parameter acting on said optical sensor, said optical sensor being susceptible to hydrogen contamination;

b) a processing entity in communication with said optical sensor for processing the response to derive a measure of the physical parameter intensity corrected for hydrogen contamination, said processing including determining from information contained in the response a degree of attenuation an optical signal manifests in at least at two different ranges of wavelengths of light, while in said optical sensor.

31) An apparatus as defined in claim 30, wherein the physical parameter is selected from the group consisting of temperature, pressure and mechanical strain.

32) An apparatus as defined in claim 31, wherein said optical sensor defines an optical path, said optical sensor includes a first optical component and a second optical component in said optical path, said first optical component and said second optical component capable to filter out from an optical excitation propagating in said optical path different ranges of wavelengths of light.

33) An apparatus as defined in claim 32, wherein said optical sensor includes a continuous length of optical fiber, said first and second optical components being located in said continuous length of optical fiber.

34) An apparatus as defined in claim 33, wherein said first and second optical components include gratings.

35) An apparatus as defined in claim 34, wherein said gratings manifest in response to a temperature change a shift in the ranges of wavelengths filtered out from the optical excitation.

36) An apparatus as defined in claim 35, wherein said gratings are selected from the group consisting of Bragg gratings and long period gratings.

37) An apparatus as defined in claim 36, wherein said response conveys:
   a) information on the range of wavelengths of light in the optical excitation filtered out by said first optical component;
   b) information on the range of wavelengths of light in the optical excitation filtered out by said second optical component;
   c) information on attenuation of the optical excitation in the optical sensor occurring at the range of wavelengths filtered out by said first optical component;

d) information on attenuation of the optical excitation in the optical sensor occurring at the range of wavelengths filtered out by said second optical component.

38) An apparatus as defined in claim 37, wherein said processing entity using the information a, b, c and d as factors in deriving information on hydrogen concentration in a core of said continuous length of optical fiber.

39) An apparatus as defined in claim 37, wherein said processing entity using the information a and b as factors in deriving information on the intensity of the physical parameter acting on said optical sensor.

40) An apparatus as defined in claim 37, wherein said processing entity includes software code to process the information a, b as factors in deriving information on the intensity of the physical parameter acting on said optical sensor.

41) A method for measuring a physical parameter in a sensing zone, said method comprising:

a) placing an optical sensor in the sensing zone, the optical sensor including a plurality of optical components responsive to the intensity of the physical parameter acting on the optical sensor, the optical sensor being susceptible to contamination by hydrogen potentially present in the sensing zone which alters the response manifested by the optical components to the physical parameter;

b) introducing an optical excitation in the optical sensor and observing the response of the optical components to the optical excitation, the optical components responding to different ranges of wavelengths of light in the optical excitation;

c) processing the response of the optical components to derive a measure of the physical parameter intensity corrected for hydrogen contamination.

42)A method as defined in claim 41, including determining a degree with which the optical components attenuate an optical signal propagating in the optical sensor.

43)A method as defined in claim 42, wherein said optical components include gratings.

44)A method as defined in claim 43, wherein the gratings are located in a continuous length of an optical fiber.

45)A method as defined in claim 44, wherein said processing includes deriving a temperature of the optical sensor.

46)A method to derive information on hydrogen concentration in an optical sensor located in a sensing zone containing hydrogen susceptible to migrate into the optical sensor, comprising:

a) receiving a signal conveying a response from first and second optical components of the optical sensor to an optical excitation;

b) processing the response from the first and second optical components to derive information on hydrogen concentration in the optical sensor.

47)A method for measuring hydrogen concentration in an optical sensor, said method comprising:

a) receiving a signal conveying a response from the optical sensor to an optical excitation;

b) processing the response to derive a measure of the hydrogen concentration in the optical sensor, said processing including determining from information contained in the response a degree of attenuation an optical signal manifests in at least at two different ranges of wavelengths of light, while in said optical sensor.

48)An apparatus for measuring temperature in a well of an oil extraction installation, said apparatus comprising:

a) an optical sensor for placement in the well which contains hydrogen susceptible to migrate into said optical sensor;

b) a signal processing device for processing an optical response of the optical sensor and derive from the optical response a temperature measurement in the well corrected for effects of hydrogen migration into said optical sensor.

49)An apparatus as defined in claim 48, wherein said signal processing apparatus uses information conveyed in the optical response to effect a correction of the effects of hydrogen migration into said optical sensor.

50)An apparatus as defined in claim 49, wherein the oil extraction installation is an oil sands extraction installation.

51)An apparatus as defined in claim 50 wherein the well receives steam.

52)An apparatus as defined in claim 49, wherein said optical sensor includes first and second optical components responsive to optical excitation.

53)An apparatus as defined in claim 52, wherein the first optical component and the second optical component filter out from the optical excitation different ranges of wavelength of light.

54)An apparatus as defined in claim 53, wherein the first and second optical components are gratings.

55)An apparatus as defined in claim 54, wherein the gratings manifest in response to a change in temperature a shift in the ranges of wavelength filtered out from the optical excitation.

56)An apparatus as defined in claim 55, wherein the gratings are selected from the group consisting of Bragg gratings and long-period gratings.

57)An apparatus as defined in claim 56, wherein the optical response conveys:

a) information on a range of wavelengths of light in the optical excitation filtered out by the first optical component;

b) information on a range of wavelengths of light in the optical excitation filtered out by the second optical component;

c) information on attenuation of the optical excitation in the optical sensor occurring at the range of wavelengths filtered out by the first optical component;

d) information on attenuation of the optical excitation in the optical sensor occurring at the range of wavelengths filtered out by the second optical component.

58)A method for measuring temperature in a well of an oil extraction installation, said method comprising:

a) receiving an optical response from an optical sensor placed in the well which contains hydrogen susceptible to migrate into the optical sensor;

b) performing signal processing on information conveyed in the optical response and deriving from the information a temperature measurement in the well corrected for effects of hydrogen migration into the optical sensor.

59)A method as defined in claim 58, wherein said processing uses information conveyed in the optical response to effect a correction of the effects of hydrogen migration into the optical sensor.

60)A method as defined in claim 59 wherein the oil extraction installation is an oil sands extraction installation.

61)A method as defined in claim 60 wherein the well receives steam.

62)A method as defined in claim 59, wherein the optical sensor includes first and second optical components responsive to optical excitation.

63)A method as defined in claim 62, wherein the first optical component and the second optical component filter out from the optical excitation different ranges of wavelength of light.

64) A method as defined in claim 63, wherein the first and second optical components are gratings.

65) A method as defined in claim 64, wherein the gratings manifest in response to a change in temperature a shift in the ranges of wavelength filtered out from the optical excitation.

66) A method as defined in claim 65, wherein the gratings are selected from the group consisting of Bragg gratings and long-period gratings.

67) A method as defined in claim 66, wherein the optical response conveys:

a) information on a range of wavelengths of light in the optical excitation filtered out by the first optical component;

b) information on a range of wavelengths of light in the optical excitation filtered out by the second optical component;

c) information on attenuation of the optical excitation in the optical sensor occurring at the range of wavelengths filtered out by the first optical component;

d) information on attenuation of the optical excitation in the optical sensor occurring at the range of wavelengths filtered out by the second optical component.

68) An optical sensor for measuring temperature in a well of an oil extraction installation, the well contains hydrogen susceptible to migrate into said optical sensor, said optical sensor comprising:

a) a first optical component and a second optical component;

b) a common optical path containing said first optical component and said second optical component, said first and second optical components capable of generating an optical response to an optical excitation conveying information from which can be derived a temperature measurement corrected for effects of hydrogen migration into the optical sensor.

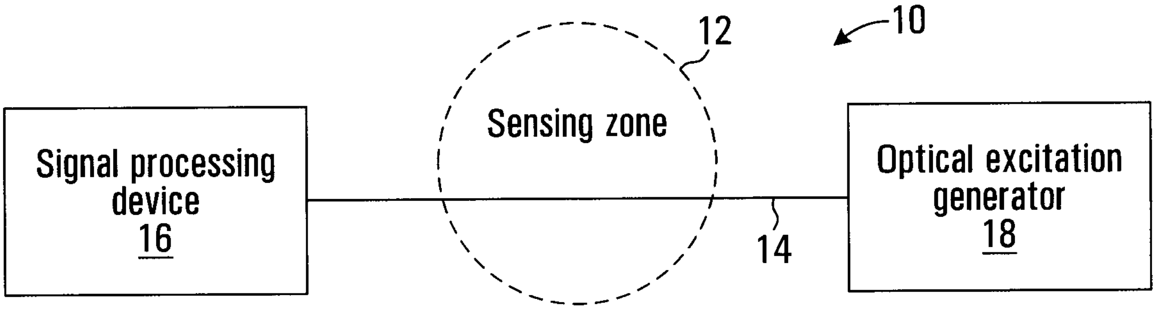

FIG. 1

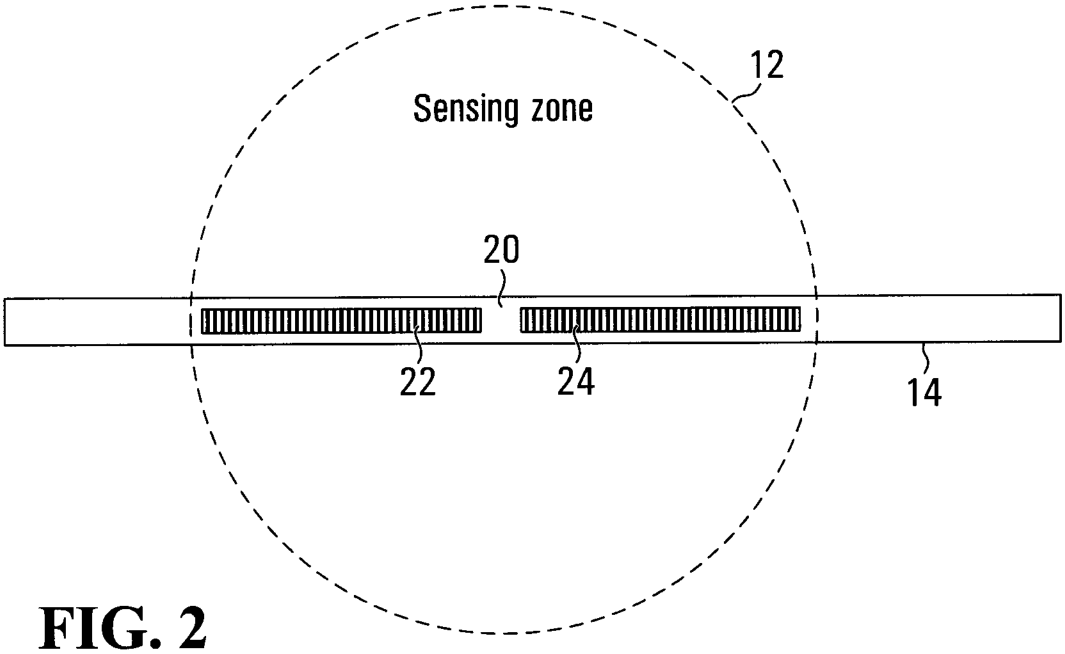

FIG. 2

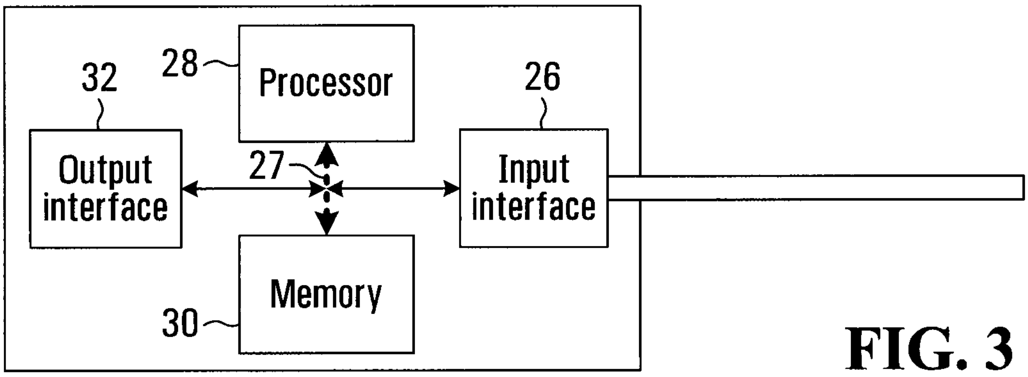

FIG. 3

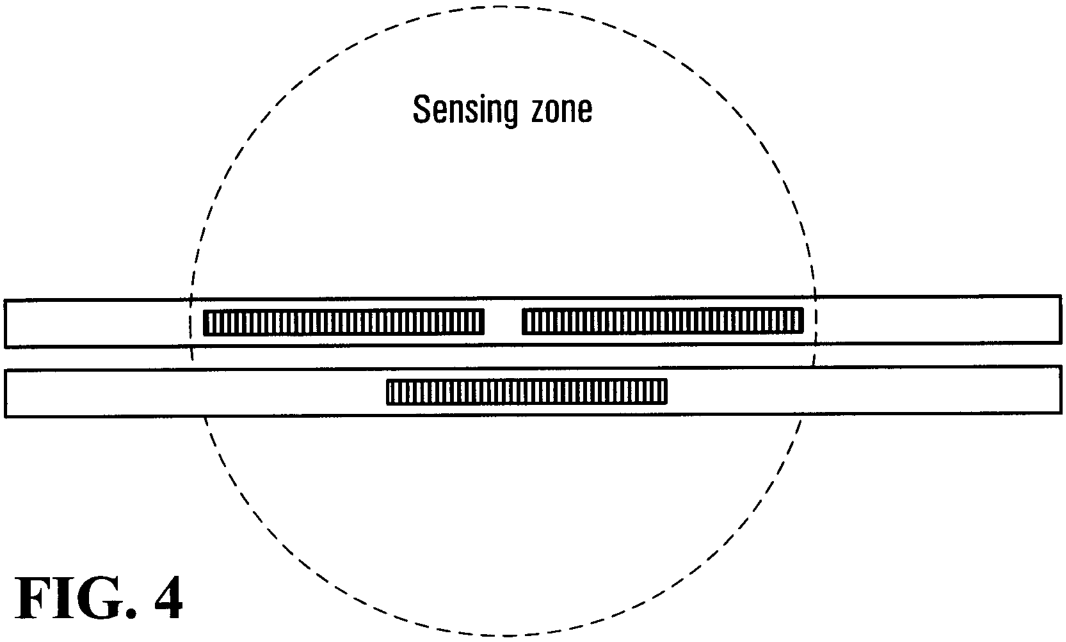
Sensing zone

FIG. 4

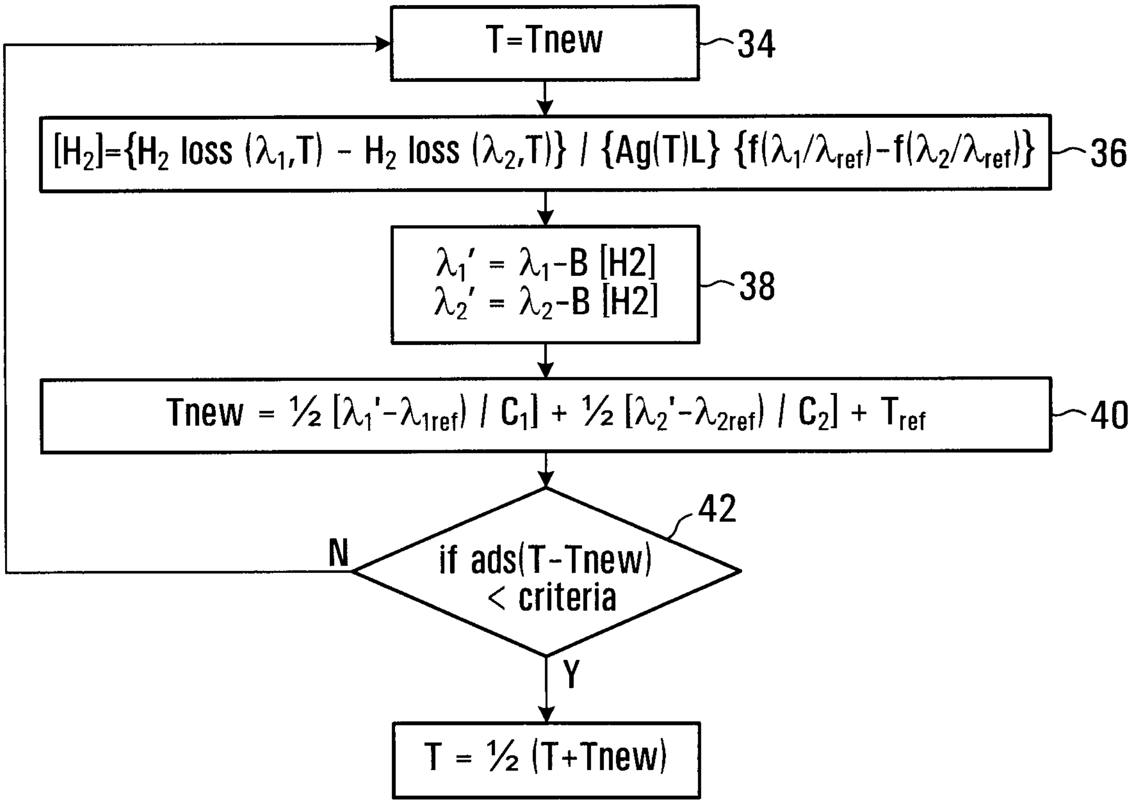
T=Tnew
34
$[H_2]=\{H_2 \text{ loss } (\lambda_1,T) - H_2 \text{ loss } (\lambda_2,T)\} / \{Ag(T)L\} \{f(\lambda_1/\lambda_{ref})-f(\lambda_2/\lambda_{ref})\}$
36
$\lambda_1' = \lambda_1\text{-B [H2]}$
$\lambda_2' = \lambda_2\text{-B [H2]}$
38
$\text{Tnew} = ½ [\lambda_1'-\lambda_{1ref}) / C_1] + ½ [\lambda_2'-\lambda_{2ref}) / C_2] + T_{ref}$
40
if ads(T-Tnew) < criteria
42
N
Y
T = ½ (T+Tnew)

FIG. 5

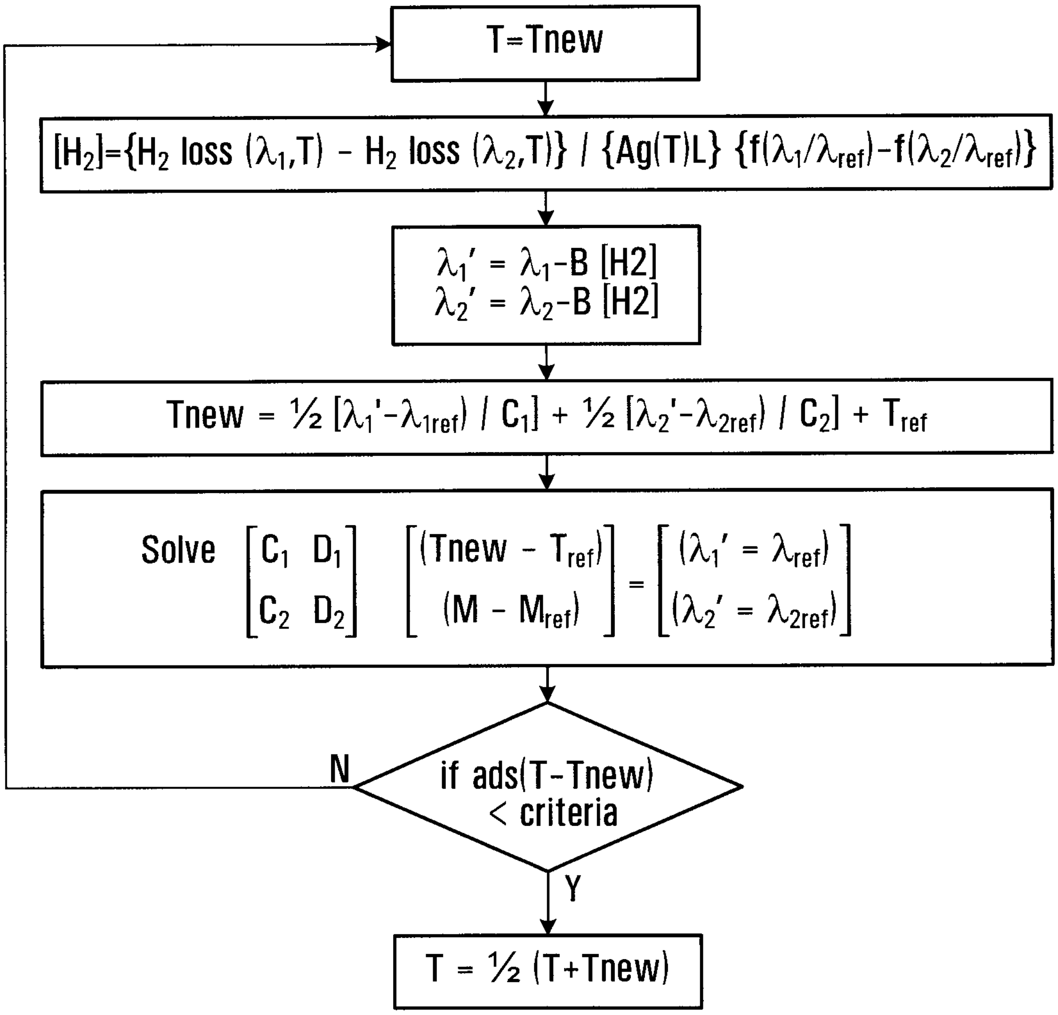
T=Tnew
[H2]={H2 loss (λ1,T) - H2 loss (λ2,T)} / {Ag(T)L} {f(λ1/λref)-f(λ2/λref)}
λ1' = λ1-B [H2]
λ2' = λ2-B [H2]
Tnew = ½ [λ1'-λ1ref) / C1] + ½ [λ2'-λ2ref) / C2] + Tref
Solve [C1 D1; C2 D2] [(Tnew - Tref); (M - Mref)] = [(λ1' = λref); (λ2' = λ2ref)]
N
if ads(T-Tnew) < criteria
Y
T = ½ (T+Tnew)

FIG. 6

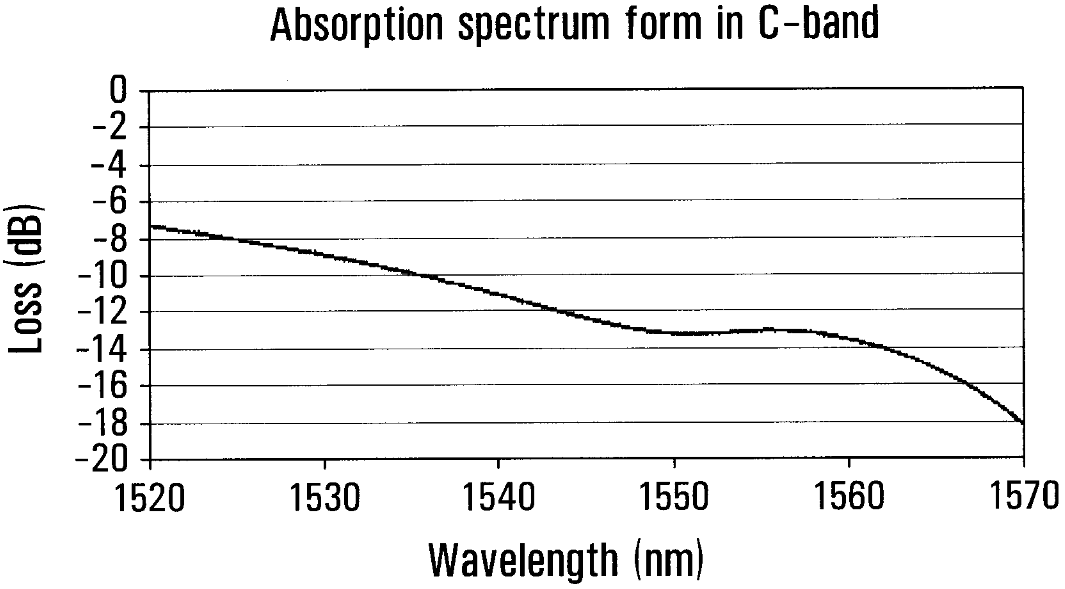
Absorption spectrum form in C-band
Loss (dB)
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
1520
1530
1540
1550
1560
1570
Wavelength (nm)

FIG. 7

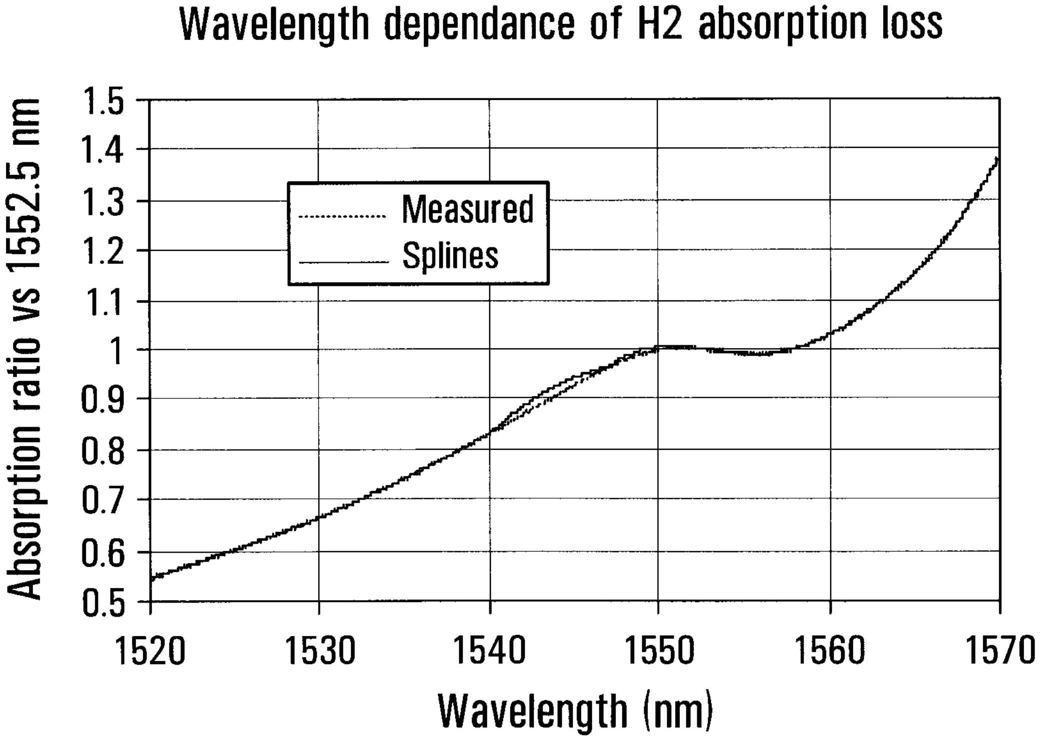
Wavelength dependance of H2 absorption loss
Absorption ratio vs 1552.5 nm
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
Measured
Splines
1520
1530
1540
1550
1560
1570
Wavelength (nm)

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2007/001545

A. CLASSIFICATION OF SUBJECT MATTER

IPC: ***G01D 3/028*** (2006.01) , ***E21B 47/06*** (2006.01) , ***G01N 21/63*** (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)

IPC (2006.01): ***G01D***, ***E21B 47/06***, ***G01N 21/63***

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

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

Canadian Patent Database, Delphion, IEEE Xplore and Internet - Search terms used: sensor, optical, “bragg grating”, refraction, filter, hydrogen, diffusion, contamination, concentration

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 2005/0118064 (BERG) 2 June 2005 (02-06-2005) abstract paragraphs [0001] - [0004] paragraphs [0016] - [0020] paragraphs [0025], [0026], and [0029] claims 1, 11, 23, 26 figures 1, 2, and 5	1-5, 16-19, 46, 48-52, 58-62 5-15, 20-45, 47, 53-57, 63-68
A	US 2005/0031981 (SAKAMOTO et al.) 10 February 2005 (10-02-2005) the entire document	1-68
A	US 2004/0165859 (MAKLAD et al.) 26 August 2004 (26-08-2004) the entire document	1-68

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

* Special categories of cited documents :

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“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 28 September 2007 (28-09-2007)	Date of mailing of the international search report 22 October 2007 (22-10-2007)
Name and mailing address of the ISA/CA Canadian Intellectual Property Office Place du Portage I, C114 - 1st Floor, Box PCT 50 Victoria Street Gatineau, Quebec K1A 0C9 Facsimile No.: 001-819-953-2476	Authorized officer Timothy Kotylak 819- 934-5150

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2004/0161215 (WILEY et al.) 19 August 2004 (19-08-2004) the entire document	1-68

Patent Document Cited in Search Report	Publication Date	Patent Family Member(s)	Publication Date
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US2004161215	19-08-2004	AU2003304260 CA2507447 A1 EP1576395 A2 US7046886 B2 WO2005001516	13-01-2005 06-01-2005 21-09-2005 16-05-2006 06-01-2005