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División de Nuevas Creaciones

SOLICITUD
PATENTE DE INVENCION

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54. TITULO

SISTEMA PARA LA MEDIDA Y ADQUISICION DE DATOS PARA SENSORES
DE FIBRA OPTICA

51. CLASIFICACION INTERNACIONAL

71. SOLICITANTE

PETROLEO BRASILEIRO S.A.-PETROBRAS

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Rio de Janeiro, RJ, Brasil

74. APODERADO

EMILIO FERRERO

C.C. 438.019 de Usaquén.

22. BOGOTA, D.C.,



Industria y Comercio
SUPERINTENDENCIA

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SUPERINDUSTRIA Y COMERCIO

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Dependencia: 2920 DIVISION DE NUEVAS CREACIONES

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SOLICITUD DE:

1

☒ Patente de Invención.

☐ Patente de Modelo de Utilidad.

2

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Cual

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3

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Título (54)

**SISTEMA PARA LA MEDIDA Y ADQUISICIÓN DE DATOS PARA
SENSORES DE FIBRA OPTICA**

6

Clasificación Internacional (51) G01D 5/00

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10 de agosto de 2004

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8

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Otro ☐

Cual _____

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Comprobante de pago N.º: 05.53.304

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Fecha: 18 de julio de 2005

11 de julio de 2005

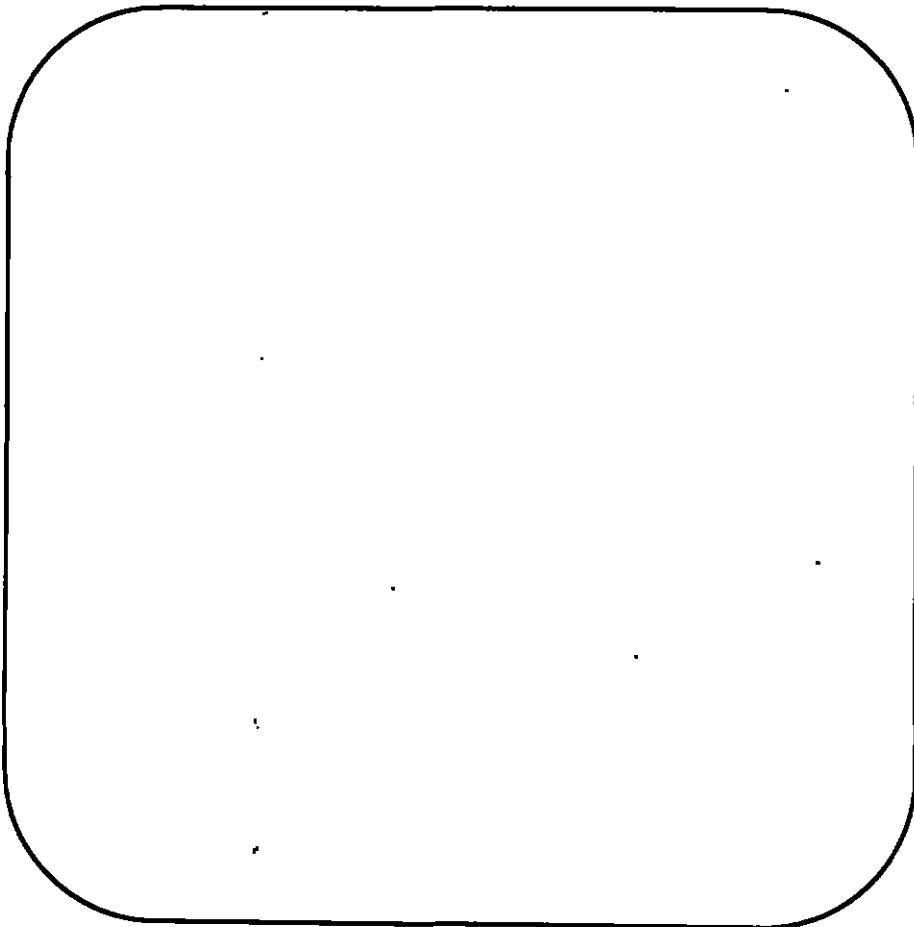
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Anex s:

- ☒ Comprobante de pago de la tasa de presentación de la solicitud.
- ☐ Comprobante de pago de la tasa por concepto de excedente de palabras en la publicación.
- ☒ Comprobante de pago por reivindicación de prioridad.
- ☒ Documento que acredita la existencia y representación legal cuando el solicitante sea persona jurídica.
- ☒ Poderes, si fuere el caso.
- ☐ Certificado de la fecha de presentación de la solicitud prioridad expedida por la autoridad correspondiente y una copia certificada de la primera solicitud si se reivindica prioridad.
- ☐ Traducción simple de la primera solicitud, si se reivindica prioridad.
- ☐ Documento de cesión del inventor al solicitante o a su causante.
- ☒ Resumen
- ☒ Descripción de la invención.
- ☒ Una o más reivindicaciones.
- ☒ Dibujos y/o planos necesarios
- ☐ De ser el caso, copia del contrato de acceso.
- ☐ De ser el caso, documento que acredite la licencia o autorización de uso de conocimientos tradicionales de las comunidades indígenas.
- ☐ De ser el caso, certificado de depósito del material biológico.
- ☐ Arte final 12x12
- ☐ De ser el caso, información sobre otras solicitudes de patente o títulos obtenidos en el extranjero por el mismo titular o su causante, relacionadas parcial o totalmente con la invención de esta solicitud.

11

FIGURA CARACTERÍSTICA



12

Solicito la concesión de la patente,

NOMBRE:

EMILIO FERRERO

FIRMA:

C.C. 438.019 de Usaquén T.P. 31.929

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3

CAVELIER

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ABOGADOS
EDIF. NO BISKI
CARRERA 4 N° 72-35
BOGOTÁ - COLOMBIA

Poder con certificado consular para patentes, modelos de utilidad, diseños industriales, marcas de fábrica, nombres comerciales, marcas, lemas comerciales, licencias y nombres de dominio de Internet.

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PODER

POWER-OF-ATTORNEY

Yo (nosotros), abajo firmado (a) (we), the undersigned

PETRÓLEO BRASILEIRO S/A - PETROBRAS

domiciliado (a) en/of Av. República de Chile, n° 65

RIO DE JANEIRO, BRASIL

por el presente nombramos a EMILIO FERRERO, tpa. 31929; GONZALO PERDOMO, tpa. 831; LUZ CLEMENCIA DE PAEZ, tpa. 23555 y GERMAN CAVELIER, tpa. 832, domiciliados en la Carrera 4 N° 72-35, Bogotá, Colombia, el primero como principal y los demás como suplentes, en su orden, y confiero (confirmando) poder a los abogados arriba nombrados para obtener la protección de mi (nuestra) propiedad industrial y contra la competencia desleal, a cuyo efecto autorizo (autorizo) a los dichos apoderados para que me (nos) representen ante cualesquiera entidades o personas, ojeran o no jurisdicción, especialmente ante las del orden administrativo, contencioso-administrativo y judicial, así como los tribunales de arbitramento, en todo lo concerniente a los siguientes asuntos: a) Obtención de patentes de invención, modelos de utilidad y diseños industriales; el registro de marcas de fábrica, colectivas, defensivas, de servicio, lemas comerciales, nombres comerciales, emblemas, variedades vegetales y denominaciones de origen; su renovación, traspaso, cambio de nombre o domicilio, cancelación voluntaria; y el registro de licencias de uso de esos derechos; b) Las acciones de competencia desleal, protección del consumidor, oposiciones u observaciones, cancelación administrativa y judicial, nulidad, medidas cautelares, cancelación de licencias, la tutela, la protección de secretos industriales, y en general los juicios civiles, penales, administrativos o contencioso-administrativos relacionados con estos derechos; acciones y procesos que promovamos o se nos promuevan; c) registros de nombre de dominio de Internet, su renovación, traspaso, cambio de nombre, cambio de domicilio y demás actos relacionados con su administración. Y para que en todos los asuntos arriba determinados, puedan sustituir este mandato, transigir, conciliar, admitir los hechos del proceso, demostrar, cancelar, recibir, renunciar, ser contactos administrativos y de pago y ratificar los actos de agentes oficiales.

do hereby appoint EMILIO FERRERO, tpa. 31929; GONZALO PERDOMO, tpa. 831; LUZ CLEMENCIA DE PAEZ, tpa. 23555 and GERMAN CAVELIER, tpa. 832, domiciled at Carrera 4 N° 72-35, Bogotá, Colombia, the first as principal and the others as alternates, in the order of their appointment, as my (our) attorneys-at-law so that they may obtain the protection of my (our) industrial property and against the unfair competition, for which purpose I (we) authorize the said attorneys to represent me (us) before any authorities or persons, with or without jurisdiction, specially those administrative, administrative contentious and judicial, as well as before Arbitration Court, in all matters concerning the following: a) Obtainment of patents, utility models and industrial designs; the registration of trademarks, collective, defensive and service marks, slogans, commercial names, trade emblems, vegetal varieties and denominations of origin; its renewal, assignment, change of name or domicile, voluntary cancellation; and the registration of licenses of use of the above rights; b) Actions of unfair competition, protection to the consumer, oppositions or observations, administrative Court cancellation, nullity, infringement, granting of licenses, the action for writ mandamus, the protection of trade secrets, and in general the civil, penal, and administrative suits relating to these rights; actions and suits instituted by me (us) or against me (us); c) registration of Internet domain names, renewal, assignment change of name or domicile and any other activity related their management. And that in all the above matters they may substitute this Power of Attorney, compromise, conciliate, admit the facts of the case, testify, cancel, receive, resign, act as administrative and/or payment contacts and ratify acts done by representatives without a power of attorney.

Dado y firmado hoy/Given and signed this

September 06, 2000

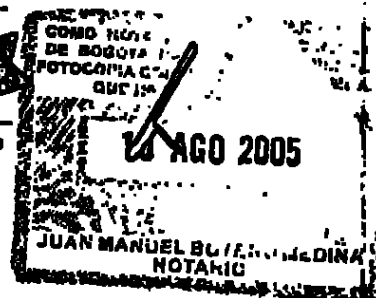
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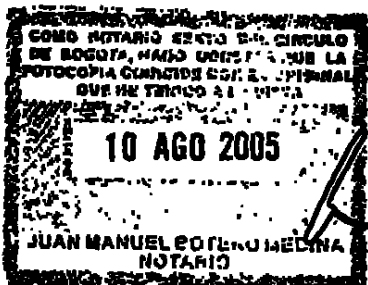
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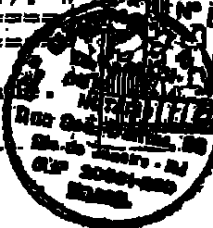
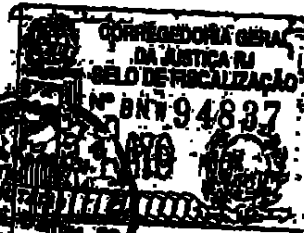
NOTÁRIO WILHAMI DE OLIVEIRA

222 Ofício de Notas - Matriz - Notários WILHAMI DE OLIVEIRA
Rua Senador Dantas, 35 - RJ - Tel. 544-0277 - NR 190259

Peconeco por semelhança a(s) firma(s): #
CARLOS SOLIGO CAMERINI-785/28, #=====

Rio de Janeiro, 12 de Setembro de 2000 as 11:30:24
Em Teste de Verdade

MARIA ANTONIA DE ALBUQUERQUE - Substituto - NAB
Válido somente com selo de fiscalização. Total 2,67



CONSULADO GENERAL DE COLOMBIA

CONSULADO DE COLOMBIA
No. 70/00.

El Suscrito Cónsul General de Colombia en Rio de Janeiro, visto los documentos presentados por los interesados, CERTIFICA: Que la Señora MARIA ANTONIA DE JESUS CORREIA, quien como Escribiente Sustituta de la Notaría 22º. de Rio de Janeiro, Brasil, autenticó la firma del signatario del poder precedente, ejercía en la fecha las funciones indicadas y su firma corresponde a la registrada en este Consulado.

Que la Compañía PETROLEO BRASILEIRO S.A. – PETROBRAS, es una sociedad constituida de acuerdo con las leyes del Brasil y cumple su objetivo conforme a las mismas.

Que el Señor CARLOS SOLIGO CAMERINI, quien en su carácter de SUPERINTENDENTE GENERAL DEL CENTRO DE PESQUISAS Y DESARROLLO de la citada Compañía, confiere el poder precedente y cuya firma fué autenticada ante la Notaría 22º. de Rio de Janeiro, Brasil, es su representante legal en este país.

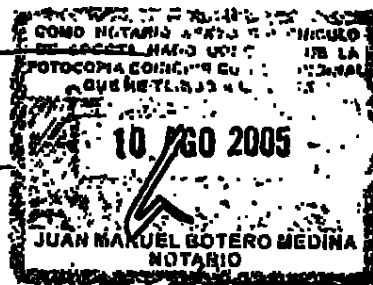
El Cónsul no asume responsabilidad por el contenido de este documento.

Rio de Janeiro, 14 de septiembre de 2000.



JUAN LOZANO P.
Cónsul General de Colombia.

PAGADO IMPUESTO DE TIMBRE
US\$ 7,00 (SIETE DÓLARES)
PAGADO DERECHOS CONSULARES
US\$ 100,00 (CIEN DÓLARES)



MINISTERIO DE RELACIONES
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Leon Pizarro

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CUYA FIRMA AUTORIZA
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QUERZ
10 AGO 2005
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NOTARIO

JEFE DE LEGALIZACIONES
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LEGALIZACIONES

Escritas en PORTUGUES, al ple de un PODER escrito en ESPAÑOL, otorgado por PETRÓLEO BRASILEIRO S/A-PETROBRAS, a EMILIO FERRERO y otros.

NOTARIA 22 - NOTARIO WILHAMI DE OLIVEIRA

Notaría 22 - Matriz - Notario: Wilhami de Oliveira

Rua Senador Dantas, 39 - Rio de Janeiro- No. 190259

Reconozco por semejanza la firma de : CARLOS SOLIGO CAMERINI -785/28

Rio de Janeiro, 12 de septiembre de 2000.-11:30:26

En fe de lo cual firmo el presente

(Firma ilegible)

MARIA ANTONIA DE JESUS CORREIA -Suplente - MAJC -1

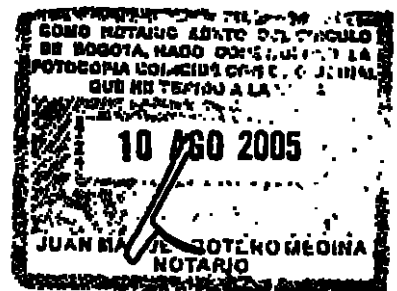
Válido únicamente con el sello de Control - Total derechos: 2,47

Sello de la Corregiduría General de Justicia

SELLO DE CONTROL

No. BN w 94837

Sello del Notario



EN ESPAÑOL, la legalización de la firma anterior por el Consulado General de Colombia en Río de Janeiro, bajo el No. 70/00 de fecha del 14 de septiembre de 2000.

EN ESPAÑOL, la legalización de la firma anterior por el Ministerio de Relaciones

Exteriores de Colombia, bajo el No. 438547 de fecha del 20 de septiembre de 2000.

ES TRADUCCION FIEL Y COMPLETA.

Traductora: María Eugenia Sanint

Bogotá, 25 de septiembre de 2000

María Eugenia Sanint
MARIA EUGENIA SANINT
TRADUCTORA OFICIAL
REGISTRO DE LA SECRETARIA DE JUSTICIA
BOGOTÁ, 25 DE SEPTIEMBRE DE 2000
DEL MINISTERIO DE JUSTICIA

~~DEBOY~~ HAGO CONSTAR QUE LA(S) FILLIA(S)

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SANTAFE DE BOGOTA, 26 SET. 2000

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RESPONSE: 10-25-15

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JUAN MANUEL NOT FOLLOINA
NOTARIO

10 AUG 2005

JUAN MANUEL BOTOLLODINA
NOTARIO

SYSTEM FOR THE MEASUREMENT AND DATA ACQUISITION FOR OPTICAL FIBER SENSORS

FIELD OF THE INVENTION

The present invention relates to a system for the measurement and data acquisition for optical fiber sensors, more specifically, to an interface for the measurement and data acquisition for Fiber Bragg grating temperature and pressure optical fiber sensors to be used in oil and/or gas wells.

BACKGROUND OF THE INVENTION

Since the seventies, when optical telecommunications based on sufficiently low attenuation were developed to allow the propagation of light to distances longer than 1 km, huge progress has been made in order to develop at the same time techniques using optical fibers designed for the measurement of a wide variety of physical, chemical and even biological quantities.

The main reasons for these efforts are some features inherent to optical fibers such as low weight, flexibility, long transmission distance, low reactivity, electrical insulation and electromagnetic immunity. Besides, there is in many cases the possibility of multiplexing the signals of several sensors, including those directed to the measurement of different quantities and even the possibility of carrying out measurements continuously distributed along the sensing fiber.

Optical fiber sensors are, therefore, optical sensors utilizing fibers as a connecting means for light between the measurand and the measurement area. Optical fiber sensors can be divided between extrinsic and intrinsic. In the first category are those where the fiber is only a waveguide and the optical effect to be measured occurs out of the fiber. In the second case the fiber is also a medium where the coupling between the measurand and the light occurs, this rendering this kind of sensor more practical under the mechanical point of view. Sensors can also be considered as for the kind of optical effect to be measured, such as a change in intensity, in polarization, in the spectrum or in the phase of the light wave.

Since the nineties a new component is becoming more and more important not only in telecommunications but also in various applications in the sensor field. This component, called fiber Bragg grating (FBG) is nothing more than a reflective optical fiber having an extremely high spectral selectivity. Its setup is based in the

generation of a periodical modulation in the refractive index of the fiber core, such structure being able to efficiently reflect the λ_b wavelength satisfying the first order Bragg condition for normal incidence, that is, equation (1) below:

$$\lambda_b = \Lambda / 2n \quad (1)$$

5 where Λ is the spatial period of the index modulation and n is the refractive index of the fiber.

The sensing ability of the Bragg gratings is related to the fact that λ_b can be altered by mechanical efforts modifying the structure periodicity, Λ , or through temperature that modifies the refractive index n . Such dependencies can be approximately summarized in the expression of equation (2) below:

$$\Delta\lambda_b / \lambda_b = 9 \times 10^{-6} \Delta T + 0,78 \varepsilon \quad (2)$$

10 Where ΔT is measured in degrees Centigrade ($^{\circ}\text{C}$) and ε is dimensionless (m/m). The numerical constants are those typical of the material of which the fiber is made up, and particularly, the thermal constant, can vary depending on the fiber.

The information provided by FBG's is contained in spectra, which renders the measurement an absolute, easy to multiplex quantity and makes Bragg gratings particularly attractive for use in sensors.

15 For usual wavelengths (1300nm and 1550nm) equation (2) implies that the measurement of λ_b should be performed at an accuracy of the order of 1 pm in order to obtain an accuracy of 1 ppm (1 $\mu\text{m}/\text{m}$) strain or 0.1 $^{\circ}\text{C}$ in temperature. There are several ways of reaching this objective, as will be seen below.

20 Based on the modifications brought about in the fiber Bragg grating optical spectrum of reflection, different procedures can be employed for the measurement of strains or temperature changes. The choice is not an obvious one and chiefly depends on the desired application, and for each case one must consider the frequency bands involved, the number of interrogated sensors, their spatial distribution, the dynamic range of strains or temperatures to be measured, space and weight limitations imposed by the measurement system and, for sure, the cost involved.

25 Some of the most widely used techniques for the measurement of Fiber Bragg grating sensors are those that use adjustable band filters for the sweeping

of the optical spectrum. To this context belongs the simplest technique consisting in the direct measurement by means of an Optical Spectrum Analyzer (OSA).

It is possible to obtain a resolution in the 1 pm range in the spectrum measurement, which corresponds to strains close to 1 $\mu\text{m/m}$ or 0.1°C temperature changes. The dynamic range for strain measurements is limited according to the number of interrogated sensors. By using two LEDs in the typical wavelengths of 1300 nm and 1550 nm, the relationship between the dynamic range, $\Delta\varepsilon$, and the number of sensors, N , can be estimated by means of the relationship below (equation (3)):

$$\Delta\varepsilon = 10^5 / N \text{ (in } \mu\text{m/m)} \quad (3)$$

Thus, for example, for the measurement of one hundred sensors using a commercial OSA, the dynamic range estimated for each measurement site is of the order of 1,000 $\mu\text{m/m}$. The main advantage of using a general purpose OSA is the simplicity and quick setting of the measurement system. However, the high cost of the equipment should be considered as well as the slowness at which is carried out the sweeping of the optical spectrum – typically, one sweeping per minute at a range of 100 nm, which practically restricts its use to static measurements. Therefore such technique should in general terms be considered for situations where the measurements are not permanent so that the equipment can be employed for additional applications. In case it is desired to measure a huge number of sensors in the same fiber, such alternative can become economically attractive.

Further, it should be pointed out that such equipment can be utilized as a fixed filter system, similar to that which will be discussed later on in the present specification. This way of utilization allows obtaining dynamic measurements (a few hundreds of Hz) but certainly should not be used in a continuous mode in view of the equipment cost. Finally, a very interesting feature is the easy calibration that can be performed, either continuously or periodically, by introducing a wavelength reference that can be made up of a gas cell or a Bragg grating in a thermally compensated encapsulation.

Fabry-Perot filters having the spectral band determined by a cavity that can be dynamically altered by for example, piezoelectric actuators, are also used for

performing spectral sweepings. In an optical circuit that can be employed together with an adjustable pass band Fabry Perot filter the pass band is made to vary in an alternate way through linear slopes, so that each of the interrogated sensors is sequentially illuminated. Resolutions close to 1 $\mu\text{m/m}$ can also be obtained through the use of this technique. The sweeping of such filters is typically limited to

5 nearly 100 nm, the frequency response hardly being higher than a few tens of Hz. Analogously to the previous case, the cost of this technique does not depend on the number of sensors to be interrogated, this rendering it more competitive as the number of measured sites is increased.

10 For systems having a not very large number of sensors, a lower cost alternative employs fixed spectral filters. Such filters can be of the Fabry-Perot kind, Mach Zender Interferometer, or even a Bragg grating as in the case of the present invention. Figure 1 attached shows optical circuits using this technique. The system employs broadband sources and the signal reflected by the grating

15 used as sensor is directed, through a 3dB coupler, to the filter and to a reference detector. The optical signal resulting from the interaction with the filter is then guided towards the other detector, and its electrical output is divided by the one obtained by the reference detector. The utilization of a reference signal aims at compensating fluctuations in the optical source. As explained in more detail

20 hereinbelow, it was experimentally found that the proposed implementation allows the measurement signal to be kept stable, with a change lower than $\pm 0.5\%$ while the power supplied by the LED is reduced in up to 30%. The topologies proposed for the measurement of four sensors, illustrated in Figure 1 attached to the present specification, can be sufficiently extended to up to 16 sensors without any

25 apparent technical problems. The utilization of two sources makes the system more robust. The cost for implementing the solutions proposed in Figure 1 is rather low for the measurement of just one sensor when compared to the acquisition of previously described equipment. As more channels are added to the system such cost increases linearly.

30 Besides the modularity, another important advantage in the utilization of fixed spectral filters is the possibility to apply such devices in dynamic measurements. The frequency range is limited by the photodetector's response and can easily reach a few hundreds of kHz. The computational modeling of the

reflection of a broadband optical signal by the sensor and then by the filter means that smaller uncertainties are obtained by using two gratings (sensor and filter) having identical spectra. Uncertainty and resolution are dictated by the photodetector frequency response. Based on simulated data it is possible to
5 estimate that for measurements in a 10Hz band, uncertainties of $\pm 0.1\%$ would be obtained in a dynamic range of $\pm 1,500 \mu\text{m/m}$.

A further set of procedures potentially applicable to the measurement of systems requiring the interrogation of several sensors is that based on time multiplexing.

10 One possibility in this area consists in the utilization of an OTDR - Optical Time Domain Reflectometer. The sensing gratings, which can be written in a same wavelength and in a same optical fiber, should bear low reflectivity, of the order of 1%. However, it should be pointed out that in view of the working principle of an OTDR the utilization of this technique is limited to static measurements.

15 Among the above-mentioned techniques, doubtless the fixed filter system is the cheapest available for a small number of sensors and it is also the system having the quickest response, with the possibility of reaching several kHz according to the electronic system. Thus, the surface data acquisition system disclosed hereinbelow in the present specification employs a fixed filter system
20 where the filters are made up of Bragg gratings.

US patent 5,401,956 teaches a practical diagnosis system working in cooperation with remote optical fiber sensors containing Bragg gratings for measuring static strain, dynamic strain and/or acoustic/vibratory perturbations of items or structures.

25 US patent 5,426,297 teaches a system allowing a plurality of Bragg grating sensors in one single fiber as well as in a plurality of fibers, each one having a plurality of Bragg gratings to be detected, such system detecting each of the wavelengths and shifts of the same reflected by the Bragg grating.

30 US patent 5,493,390 teaches a system involving a source of light, an optical fiber containing a Bragg grating forming a sensor reflecting a wavelength in response to a perturbation, integrated tunable opto-acoustical filter placed in the path of the light emitted by said sensor for filtering the light received from the sensor, the filter pass band being adjustable to superimpose to the reflection

wavelength of the sensor in response to a control signal of the filter, and to provide a filtered signal the power of which is related to the optical transmission; optical detection device for detecting the power of the filtered signal and providing a detection signal and a device for signal processing in response to the detection signal for providing the filter control signal, detecting a shift in the reflection wavelength caused by the perturbation, the signal processing device including devices for adjusting the filter control signal to follow static shifts in the reflection wavelength and dynamic shifts in the sensor wavelength caused by static and dynamic shifts in the perturbation, for a predetermined length of time, and for providing output signals able to indicate the static and dynamic shifts in the perturbation.

In spite of the approaches provided for by the state-of-the-art technique, there is still the need of a system for the measurement and surface data acquisition for fiber Bragg grating-based optical fiber pressure and temperature sensors, said system comprising: i) an optical system for signal processing with an optical source transmitting a signal through an optical coupler, said signal being conveyed to fiber Bragg grating (FBG) optical fiber sensors, the optical signals returning from said optical fiber sensors passing by couplers and divided in outputs so as to yield reference signals conveyed to detectors; ii) an electronic signal processing system, and iii) an optical switcher with an interface, connecting the optical fiber sensors containing Bragg gratings for the measurement of physical parameters such as pressure and temperature in an oil and/or gas well and the optical and electronic systems, such system for the measurement and data acquisition being described in the present application.

SUMMARY OF THE INVENTION

Broadly, the present invention comprises a system for the measurement and surface data acquisition for optical fiber sensors containing Bragg gratings for the sensing of physical parameters originated from a set of oil wells, said system comprising:

- a) an optical system for signal processing, said signals being originated from physical parameters sensors installed in one single or in a set of oil and/or gas wells and resulting from the reflected wavelength in response to a perturbation of the physical parameter under measurement;

- b) an electronic system for signal processing for converting the optical intensity signals originated from said optical system into electrical signals with the aid of detectors that optimize the signal/noise ratio; and
- c) an optical switcher having an interface between a) and b), for expanding the number of monitored oil wells.

Thus, the invention provides a system for the measurement and surface data acquisition for fiber Bragg grating pressure and temperature optical fiber sensors to be applied in oil and/or gas wells.

Still, the invention provides a system for the measurement and surface data acquisition for fiber Bragg grating pressure and temperature optical fiber sensors where lower uncertainties are obtained by utilizing two gratings (sensor and attenuator) having identical spectra.

The invention provides further a system for the measurement and surface data acquisition for fiber Bragg grating pressure and temperature optical fiber sensors made up of an optical system for signal processing, an electronic system for the processing of said signals and an interface provided with an optical switcher between the optical system and the electronic system.

The invention provides also a system for the measurement and surface data acquisition for fiber Bragg grating pressure and temperature optical fiber sensors that attends to the demand for the monitoring of pressure and temperature in wells, for the acquisition of dynamic data.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 attached illustrates state-of-the-art optical circuits utilizing Bragg gratings as fixed pass band filters. FIGURE 1A attached shows the measurement channel and the circuit for one sensor. FIGURE 1B illustrates a circuit for four sensors in different fibers and FIGURE 1C shows the circuit for four sensors in one single fiber.

FIGURE 2 attached is a scheme of the data architecture and control for oil wells based on optical fiber sensors.

FIGURE 3 attached is a series of graphs representing the convolution between the sensor signals and those of the reference.

FIGURE 4 attached is a diagram of the optical circuit according to the invention.

FIGURE 5 attached is a block diagram of the electronic system.

FIGURE 6 attached is a block diagram illustrating the several possible arrangements of the optical switcher module.

DETAILED DESCRIPTION OF THE PREFERRED MODE

5 The invention relates therefore to a system for the measurement and surface data acquisition for fiber Bragg grating pressure and temperature optical fiber sensors to be utilized in oil and/or gas wells, the system being made up of an optical system for signal processing, an electronic system for processing said signals and an optical switcher with an interface between said optical system and
10 said electronic system.

 The data acquisition system is suitable for utilization in oil and/or gas wells. It should be pointed out that the suggested setup throughout the specification for the acquisition system is made up of individual modules that can be configured into different setups and that these setups can be expanded, according to the
15 acquisition scope and the number of sensors.

 The invention will now be described by reference to the attached Figures.

 Figure 1 is a diagram that illustrates state-of-the-art optical circuits using Bragg gratings as fixed pass band filters. Figure 1A shows the measurement channel and the circuit for one sensor. Figure 1B shows a circuit for four sensors
20 in different fibers while Figure 1C shows the circuit for four sensors in one single fiber.

 Figure 2 is a general scheme of the surface acquisition data system for oil and/or gas wells presented in the invention. Thus, pressure and temperature optical fiber sensors (10a) and (10b) containing Bragg gratings are inserted in oil
25 wells. In optical module (30) an optical source (31) connected to a modulator (32) conveys light through a coupler (33a) and an optical switcher (20) up to pressure and temperature sensors (10a) and (10b) in the oil wells. The parameters measured by sensor (10a) and by sensor (10b) are conveyed to an electronic module (40) where they are processed and converted into electrical signals
30 through detectors that optimize the signal/noise ratio.

 In order to obtain the lowest uncertainties in the measurements, two Bragg gratings should be used, that is, the sensor grating and the filter grating having identical spectra.

Figure 3 illustrates a graph for the convolution between the signals of one sensor (10a/10b) and those of the reference, that is, the comparison between the optical signals from the sensors of each channel and from their respective reference gratings. Therefore, possible fiber attenuations and changes in optical power emitted by optical source (31) are automatically compensated through the ratio between the signal directly received from the sensor (10a/10b) and the signal resulting from the convolution between signals.

Figure 4 illustrates the details of the optical module (30) used in the invention.

10 Optical source (31) is based on a super luminescent diode (SLED), the power of which is 5mW. The power is amplitude-modulated by a 1 KHz sinusoid signal, and is transmitted in one of the arms of an optical coupler (33a). The optical signal generated by source (31) is conveyed to two optical fiber sensors (10a/10b) containing fiber Bragg gratings. Sensors (10a/10b) are designed for the measurement of pressure and temperature of oil and/or gas wells and can be any commercial pressure and temperature optical fiber sensors containing fiber Bragg gratings. The return of the optical signal of the two sensors (10a/10b) crosses a coupler (33b) that divides the signal into two outputs, (Output 1) and (Output 2).

20 The optical signal of the first output (Output 1) is directed to another coupler (33c) that divides said signal into two other outputs: that of channel 1 power reference signal (RefPower 1) and that of channel 1 sensor reference signal (RefSens 1).

25 The optical signal of the second output (Output 2) is also directed to another coupler (33d), performing a processing analogous to that of Output 1, that is, it divides the signal into two further outputs: that of channel 2 power reference signal (RefPower 2) and that of channel 2 sensor reference signal (RefSens 2).

Channel 1 power reference signal (RefPower 1) is conveyed to a sensor detector (36a) by means of a 20 dB fixed attenuator (34a).

30 Analogously, channel 2 power reference signal (RefPower 2) is conveyed to a sensor detector (36b) by means of a 20 dB fixed attenuator (34b).

The correction of the dynamic range of the power ratio is obtained through utilization of attenuators (34a, 34b).

Sensors detectors (36a through 36d) are based on PINFET technology.

Sensor detector (36c) receives the signal from the convolution between the signal reflected by sensor 1 (Sens 1) and the inner fixed reference (35a) (RefSens1).

5 Analogously, sensor detector (36d) receives the signal from the convolution between the signal reflected by sensor 2 (Sens 2) and the inner fixed reference (35b) (RefSens2).

The inner reference gratings (35a, 35b) are kept at constant temperature by the use of a thermoelectric temperature controller (non-represented).

10 In short, for the calculation of the parameters measured by sensor 1 (10a), one evaluates the ratio between the optical intensity of the signal of sensor detector (36c) (convolution 1) and that of sensor detector (36a) (channel 1 power reference – RefPower1).

15 Analogously, for the calculation of the parameters measured by sensor 2 (10b), one evaluates the ratio between the optical intensity of the signal of sensor detector (36d) (convolution 2) and that of sensor detector (36b) (channel 2 power reference – RefPower2).

Figure 5 details the module (40) for electronic signal processing.

20 In module (40), the optical intensity signals are converted into electrical signals through detectors (41a, 41b, 41c, 41d) that optimize the signal/noise ratio. These detectors are also of the PINFET type.

25 Aiming at rendering detection circuits immune to the offset tensions of the input electronic circuits so as to obtain a thermally stable measurement system and making possible the exact measurement of very low powers, one uses the amplitude modulation by a 1KHz sinusoid signal at the optical source (31) and respective demodulation in detecting circuits (41a, 41b, 41c, 41d).

30 Electrical signals resulting from detectors (41a, 41b, 41c, 41d) are conditioned and filtered with the aid of low pass filters (LPF) (42a, 42b, 42c, 42d). Then, the signals are converted to digital form using an analog-digital converter (A/D) at a rate of 64 kbits/s, so that a digital signal processor (DSP) (43) processes the signals.

DSP (43) allows the calculation of the ratio of the two power signals already converted from analog to digital in each sensor (10a, 10b) and the synchronous

detection of the two signals resulting from the ratio (Intensity peaks) through a Fast Fourier Transform (FFT) with the Hanning window.

In order to improve the dynamic range by the need of a more powerful and stable source of light it is recommended to utilize a temperature-stable super luminescent diode (SLED) (31), the temperature being stabilized with the aid of a
5 TEC (Thermo Electric Cooler - Peltier) (44).

The same temperature-stabilizing effect is obtained in the inner reference fixed filters (F1 and F2) using TEC. Through the temperature control the repeatability of measurements is assured.

10 The PXI/cPCI (45) aims at converting data from related optical intensity measurements with the changes in physical quantities, said data being digitalized by the Analog Digital Converter (ADC) of the Digital Signal Processor (DSP) towards the CPU via standard Industrial PXI backplane for further processing.

CPU (46) allows processing the optical intensity signals collected from the
15 sensors (reference electrical signals, and source of light converted and digitalized) with data of the specific calibration curves for each sensor (10a, 10b) rendering such correlation into physical magnitudes such as pressure and temperature, the control of the equipment working status and the communication with the outer device) (controller or supervising system).

20 Figure 8 schematically details the modes of module (20) of the optical switcher: multiplexed in 1:2 (21), 1:4 (22) and (23) without switcher. The outer optical switches are controlled by system CPU (46) and allow to expand the number of monitored wells, in this case up to four wells at the same time, provided the gratings of all sensors have the same wavelength and shape (matched to the
25 reference filters) of the inner references (reference FBG filters of the equipment).

The multiplexing options of the optical switchers have at least ten million cycles useful life and are controlled from outside by a serial signal.

It should be pointed out that all the circuits (detectors and sources of light) are setup in one single printed circuit board in order to attend to the compaction
30 requirement.

The objective of the measurement and data acquisition system of the invention is to be used in an industrial environment (well surface) so as to secure

the main features of the system: robustness, compaction and noise immunity EMI/RFI

As an integral part of the system, it is worthwhile to mention the developed software, which includes signal processing (FFT with Hanning window) in DSP (43), calibration curves, status and management of the system working in CPU (46)

The working of the proposed system is based on the relative measurement of the optical power, since what is processed is the ratio between the signals from each optical sensor element and its respective reference channel.

The use of modulation techniques of the optical source and the respective demodulation in the detecting circuits allow to reach reduced off-set levels, this being an important factor to obtain long-term stability of the measurement system.

The use of reference channels in the receptor circuits allows the automatic compensation of possible attenuations of the sensor-containing fiber, as well as changes of the emitted optical power.

The advantage in the implementation of the fixed filter with optical power reference technique is the amplitude modulation of the optical source with synchronous detection of the signals resulting from the Fast Fourier Transform, that is, the manner for the measurement of the physical magnitudes of the optical pressure and temperature (P&T) sensors involves the indirect correlation of the wavelength change into intensity change as received from each grating (sensor).

The method for measurement and return processing (light) is effected by means of the basic processing of the following parameters: measurement of source intensity, measurement of inner references resulting from each surface FBG filter, and correlation of the optical signal received from sensor (FBG filter) and its reference grating at the surface (relationship between the signal received from a grating without change in strain and temperature, with a grating/sensor with change in temperature and strain). The optical source is amplitude-modulated, and the signal of electric response is detected by processing with the aid of FFT (Fast Fourier Transform).

The present system is provided with the following advantages:

- It comprises circuits (detectors and sources of light) mounted in one single printed circuit board in order to comply with compaction requirements;

- a more powerful and stable source of light is employed, aiming at improving the dynamic range using a SLED with temperature stabilization;
 - the use of PINFET detectors leads to non susceptibility to interferences;
 - the optical filters with temperature control allow to secure the repeatability of the circuit;
- 5
- DSP (43) and CPU (46) allow the processing, measurement, storing and communication with the outer and supervisory controller; possible fiber attenuations while changes of the emitted optical power are automatically compensated;
- 10
- The system provides analog signals compatible with the A/D plate to which it is coupled;
 - It is possible to obtain very exact measurements of low optical powers;
 - The system is shielded against EM/RFI interferences.

WE CLAIM

1. A system for the measurement and surface data acquisition for optical fiber sensors containing fiber Bragg gratings for the sensing of physical quantities originated in one oil and/or gas well or in a set of oil and/or gas wells, wherein said system comprises:
 - 5 a. A signal processing optical system (30), said signals being: i) originated from sensors (10a,10b) for sensing physical parameters installed in one oil and/or gas well or in a set of oil and/or gas wells and ii) resulting from reflected wavelength in response to a perturbation in the physical quantity under measurement;
 - 10 b. A signal processing electronic system (40) for converting the optical intensity signals originated from said optical system (30) into electrical signals through detectors (36a, 36b, 36c, 36d) that optimize the noise/signal ratio; and
 - 15 c. An optical switcher (20) having an interface between a) e b), to expand the number of monitored oil and/or gas wells.
2. A system according to claim 1, wherein the physical quantities are pressure and temperature.
3. A system according to claim 1, wherein the gratings of sensor (10a/10b) and fixed attenuator (34a/34b) should have identical spectra.
- 20 4. A system according to claim 1, wherein sensors (10a,10b) are designed to the measurement of pressure and temperature of oil and/or gas wells.
5. A system according to claim 1, wherein sensors (10a, 10b) are any commercial sensors using Fiber Bragg grating technology provided that the reference gratings and the sensor gratings have the same spectrum.
- 25 6. A system according to claim 1, wherein in optical module (30) an optical source (31) connected to a modulator (32) conveys light through a coupler (33a) and an optical switcher (20) until sensors (10a) and (10b) in the oil and/or gas wells, the parameters measured by sensor (10a) and by sensor (10b) being directed to an electronic module (40), where they are processed and converted into electrical signals through detectors (36a, 36b, 36c, 36d) that optimize the signal/noise ratio.
- 30

7. A system according to claim 6, wherein optical source (31) is based on a 5mV power super luminescent diode SLED, said diode being amplitude-modulated by a 1 kHz sinusoidal signal.
8. A system according to claim 6, wherein said system comprises:
- 5 a. Transmitting the optical signal generated by source (31) to one of the arms of an optical coupler (33a) and conveying said signal to sensors (10a,10b), the return of the optical signal of the two sensors (10a,10b) crossing a coupler (33b) that divides the signal into two outputs, (Output 1) and (Output 2);
 - 10 b. Directing the optical signal of the first output (Output1) to a further coupler (33c), said signal being divided in two further outputs: channel 1 power reference signal (RefPower1) and channel 1 sensor reference signal (RefSens1);
 - 15 c. In a way analogous to that of b), also directing the optical signal of the second output (Output 2) to a further coupler (33d), and dividing said signal in two further outputs: channel 2 power reference signal (RefPower2) and channel 2 sensor reference signal (RefSens2);
 - 20 d. Conveying channel 1 power reference signal (RefPower1) to a detector (36a) through a fixed 10 dB attenuator (34a);
 - 25 e. Conveying in a way analogous to d), channel 2 power reference signal (RefPower2) to a detector (36b) through a fixed 10 dB attenuator (34b);
 - 30 f. Arranging for detector (36c) to receive the signal from the convolution between the reflected signal of sensor 1 (Sens1) and the inner fixed reference (35a) (RefSens1);
 - g. Arranging in a way analogous to f), detector (36d) to receive the signal from the convolution between the reflected signal of sensor 2 (Sens 2) and the inner fixed reference (35b) (RefSens2).
9. A system according to claim 8, wherein the inner reference gratings (35a, 35b) are kept at constant temperature through the use of a thermoelectric temperature controller TEC.
10. A system according to claim 8, wherein for the calculation of the parameters measured by sensor 1 (10a), one evaluates the ratio between the optical

Intensity of the signal of detector (36c) (convolution1) and that of detector (36a) (channel 1 power reference – RefPower1).

- 5 11. A system according to claim 8, wherein for the calculation of the parameters measured by sensor 2, (10b) one evaluates the ratio between the optical intensity of the signal of detector (36d) (convolution2) and that of detector (36b) (channel 2 power reference – RefPower2).
12. A system according to claim 8, wherein the correction of the dynamic range of the power ratio is given by the utilization of attenuators (34a, 34b).
- 10 13. A system according to claim 1 wherein in module (40), the optical intensity signals are converted into electrical signals through detectors (41a, 41b, 41c, 41d) that optimize the signal/noise ratio.
14. A system according to claim 12, wherein amplitude is modulated by a 1KHz sinusoidal signal in optical source (31) and the respective demodulation is carried out in detecting circuits (41a, 41b, 41c, 41d).
- 15 15. A system according to claim 12, wherein the electrical signals resulting from detectors (41a, 41b, 41c, 41d) are conditioned and filtered with the aid of low pass band filters (LPF) (42a, 42b, 42c, 42d) and then converted into digital form by means of an analogical/digital converter (A/D), at a 64 kbits/s rate, to be processed by a digital signal processor (DSP) (43).
- 20 16. A system according to claim 1, wherein optical switcher module (20) comprises multiplexing (21) for two sensors.
17. A system according to claim 1, wherein optical switcher module (20) comprises multiplexing (22) for four sensors.
- 25 18. A system according to claim 1, wherein optical switcher module (20) is free from multiplexing (23).

ABSTRACT
SYSTEM FOR THE MEASUREMENT AND DATA ACQUISITION FOR
OPTICAL FIBER SENSORS

A system for the measurement and surface data acquisition for optical fiber
5 sensors containing Fiber Bragg Gratings (FBG) for the sensing of physical
parameters originated in one oil and/or gas well or a set of said wells is described,
said system comprising an optical system (30) for signal processing, said signals
being: i) originated from sensors (10a,10b) for sensing physical parameters
installed in one oil and/or gas well or in a set of oil and/or gas wells and ii) resulting
10 from reflected wavelength in response to a perturbation in the physical quantity
under measurement; b) a signal processing electronic system (40) for converting
the optical intensity signals originated from said optical system (30) into electrical
signals through detectors (36a, 36b, 36c, 36d) that optimize the noise/signal ratio
for electrical signals that are digitalized and converted according to an algorithm
15 using the constants of calibration curves of each sensor for determining the
physical quantities pressure and temperature; and c) an optical switcher (20)
having an interface between a) e b), to expand the number of monitored oil and/or
gas wells.

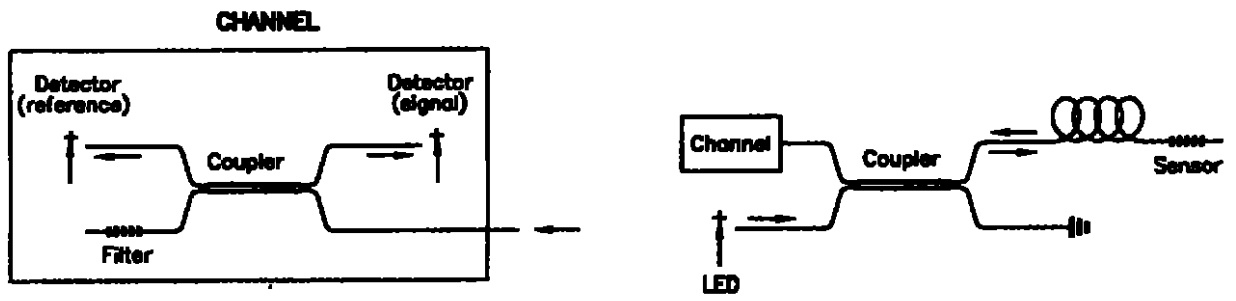


FIG. 1A

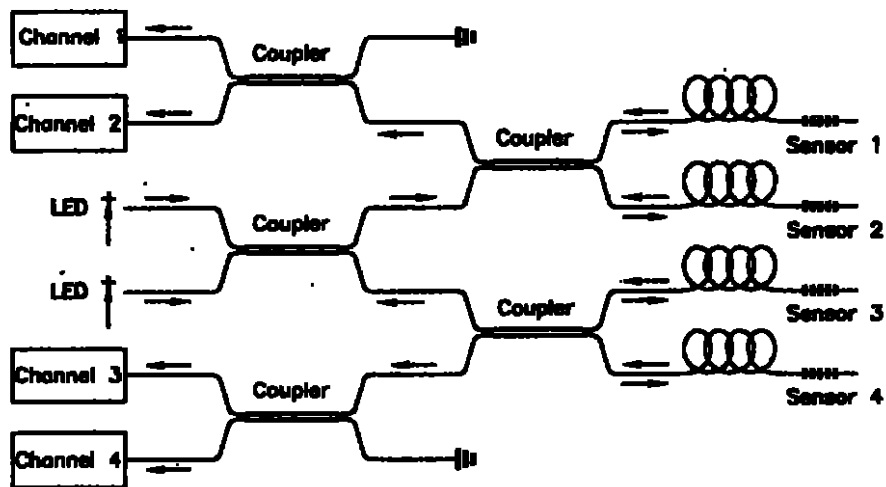


FIG. 1B

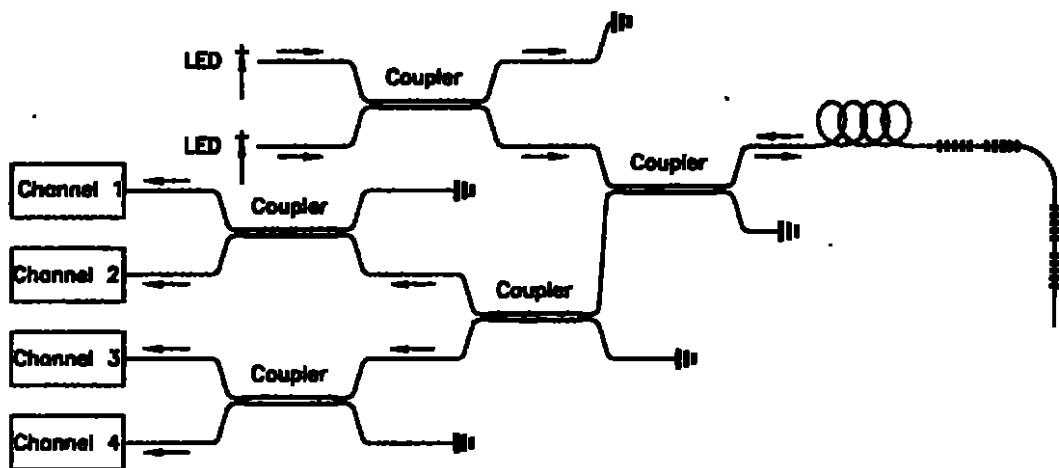


FIG. 1C

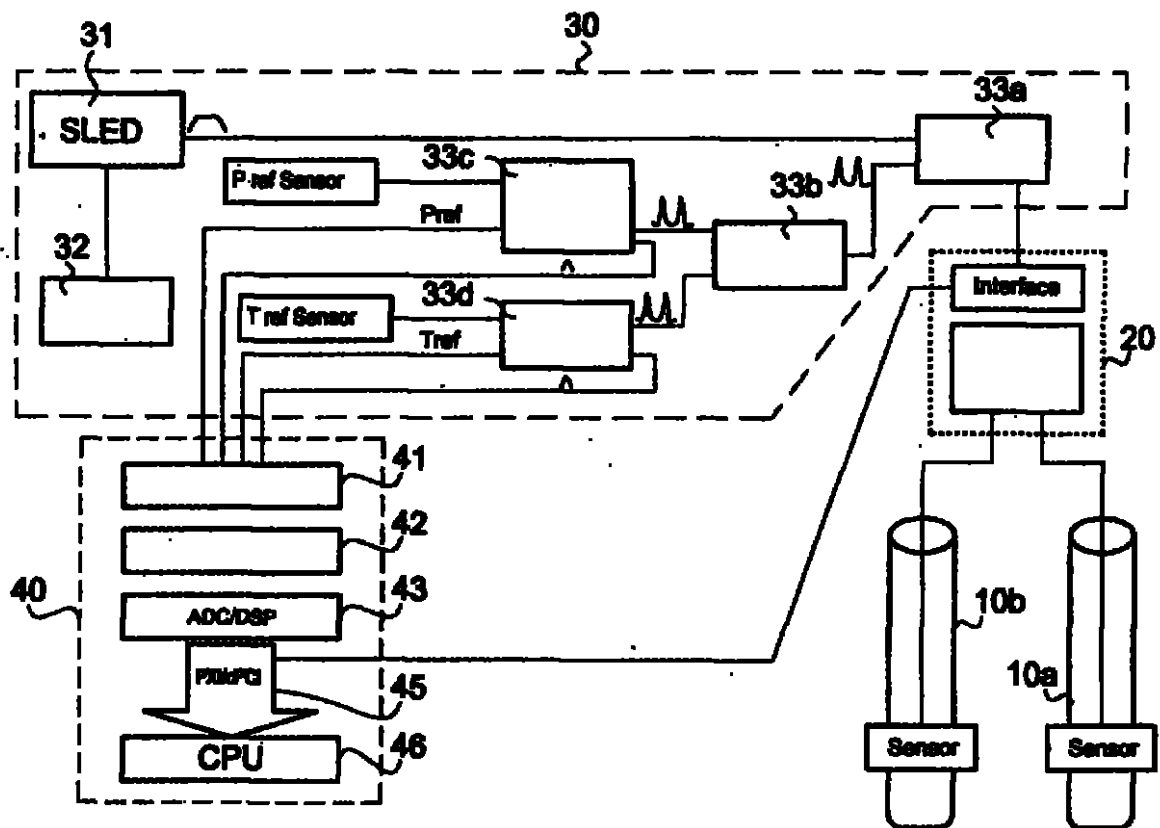


FIG. 2

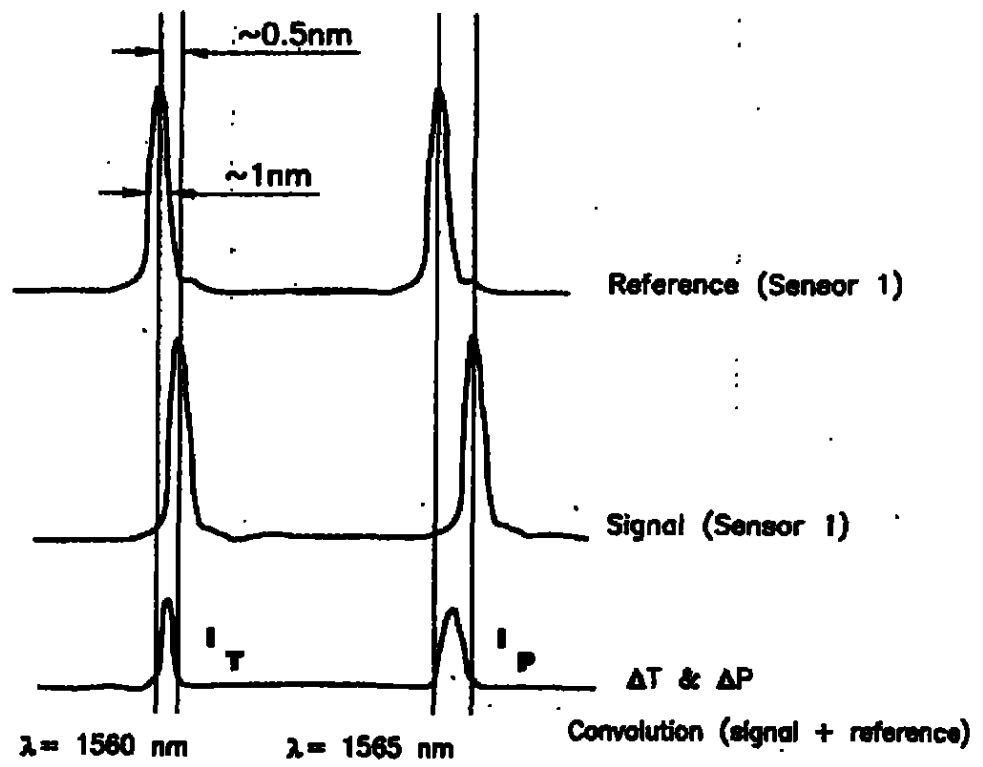


FIG. 3

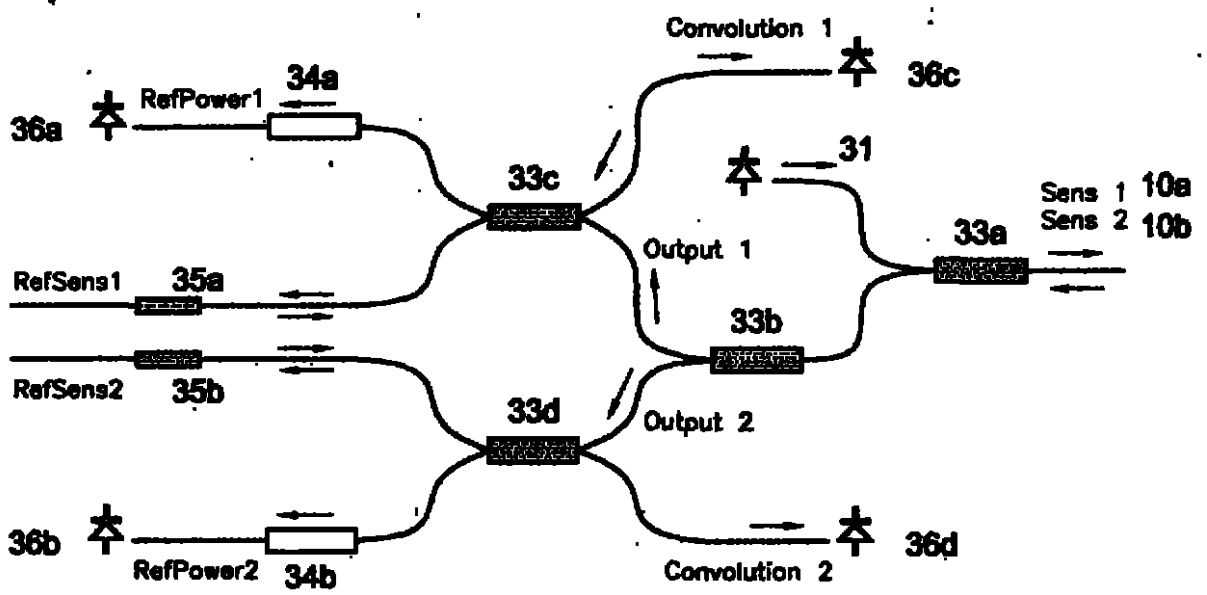


FIG. 4

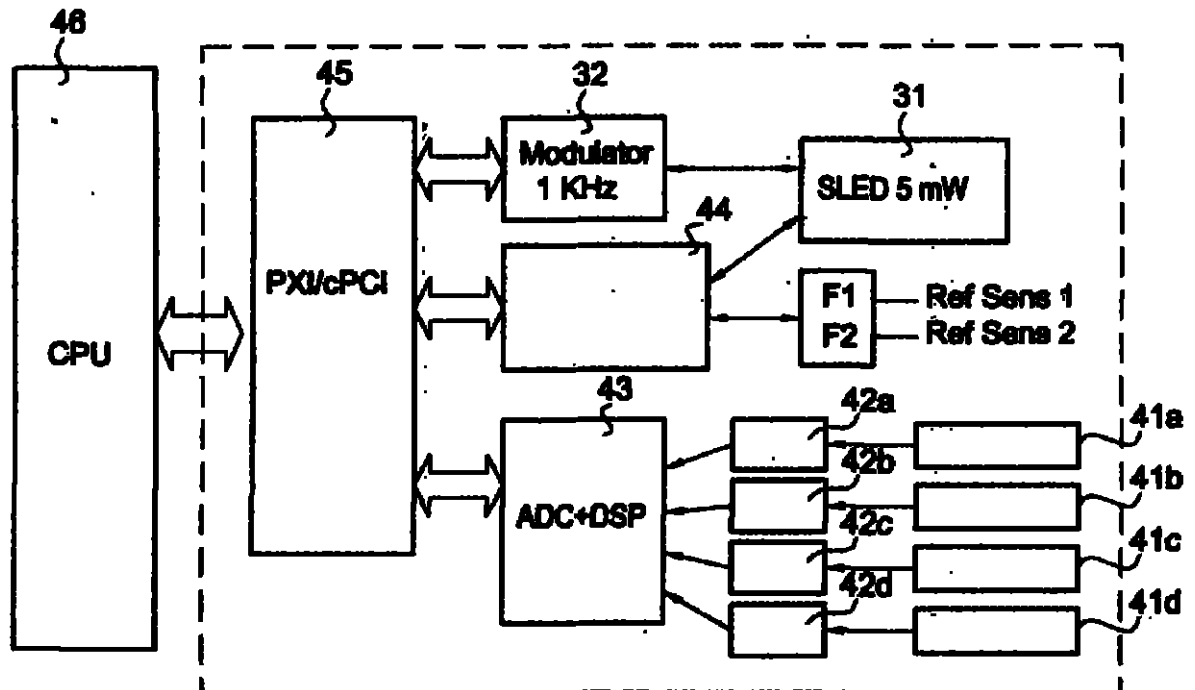
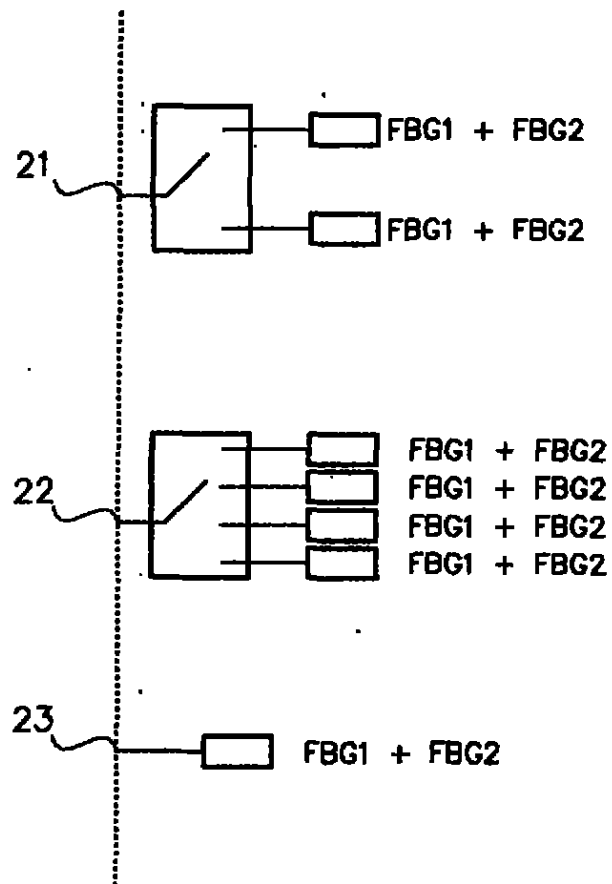


FIG. 5

**FIG. 6**

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO

NIT : 000176009-2

RECIBO OFICIAL DE CAJA : 05 - 53,304
FECHA : JULIO 18 DE 2003

SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO
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***** CONSIGNACION *****

DEPOSITANTE	TIPO PAGO	BANCO	CUENTA	No. PAGO	FECHA PGO	Vr. PAGO
CAVELIER ABOGADOS	CONSIGNACION	BANCO POPULAR	050-00110-6	31509394	18/07/2003	53,443,000.00

***** C O N C E P T O *****

CANT. HISTORICO	CONCEPTO	TOTAL CONCEPTO
1 50003-01-01 SOLICITUDES	1 TRAMITES DE SOL. DE PATENTE DE IN	443,000.00
	TOTAL :	\$ 443,000.00

SOM: CUATROCIENTOS CUARENTA Y TRES MIL PESOS

RESPONSABLE : 

RECIBO DE CAJA APLICADO AL EXPEDIENTE No. _____

Colo 00795-801-024-6

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SUPERINTENDENCIA DE INDUSTRIA Y COMERCIO

NIT : 000176009-2

RECIBO OFICIAL DE CAJA : 05 - 31,279
FECHA : JULIO 11 DE 2005

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***** CONSIGNACION *****

DEPOSITANTE	TIPO PAGO	BANCO	CUENTA	No. PAGO	FECHA PBO	Vr. PAGO
CAVELIER ABOGADOS	CONSIGNACION	BANCO POPULAR	050-00110-6	40116713	11/07/2005	65,740,000.00

***** C O N C E P T O *****

CANT. HISTORICO	CONCEPTO	TOTAL CONCEPTO
1 30005-01-01 SOLICITUDES	02 INVOCACION DE UNA PRIORIDAD EN NU.	124,000.00
	TOTAL :	124,000.00

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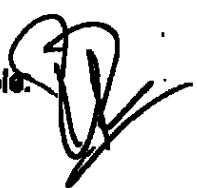
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Dependencia: 2020 DIVISION DE NUEVAS CREACIONES

REQUISITOS NECESARIOS PARA PRESENTACION Y AGILIZACION DEL
TRAMITE

	USUARIO	RADICADOR
PATENTE DE INVENCION	()	()
MODELO DE UTILIDAD	()	()
- Indicación de que se solicita la concesión de una patente.	()	()
- Datos de identificación del solicitante o de la persona que se presenta la solicitud.	()	()
- Descripción de la invención.	()	()
- Dibujos de ser estos pertinentes.	()	()
- Comprobante de Pago de las tasas establecidas.	()	()
COMPLETA ()	INCOMPLETA ()	()
DISEÑO INDUSTRIAL ()		
- Indicación de que se solicita el registro de Diseño Industrial	()	()
- Datos de identificación del solicitante o de la persona que presenta la solicitud.	()	()
- Representación gráfica o fotográfica del Diseño Industrial o muestra del Material que incorpora el diseño.	()	()
- Comprobante de pago de las tasas establecidas	()	()
COMPLETA ()	INCOMPLETA ()	()
ESQUEMA DE TRAZADO ()		
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- Datos de identificación del solicitante o de la persona que presenta La solicitud.	()	()
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- Comprobante de pago de las tasas establecidas.	()	()
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Firma Responsable:



Fecha: