PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
A61B 5/02, G01J 5/08, G01K 11/00, 11/32, G01L 11/02, G02B 6/00

A1

(11) International Publication Number: WO 96/36276

(43) International Publication Date: 21 November 1996 (21.11.96)

(21) International Application Number: PCT/AU96/00293

(22) International Filing Date: 14 May 1996 (14.05.96)

(30) Priority Data:
PN 2971 15 May 1995 (15.05.95) AU

(71) Applicant (*for all designated States except US*): THE UNIVERSITY OF SYDNEY [AU/AU]; Parramatta Road, Sydney, NSW 2006 (AU).

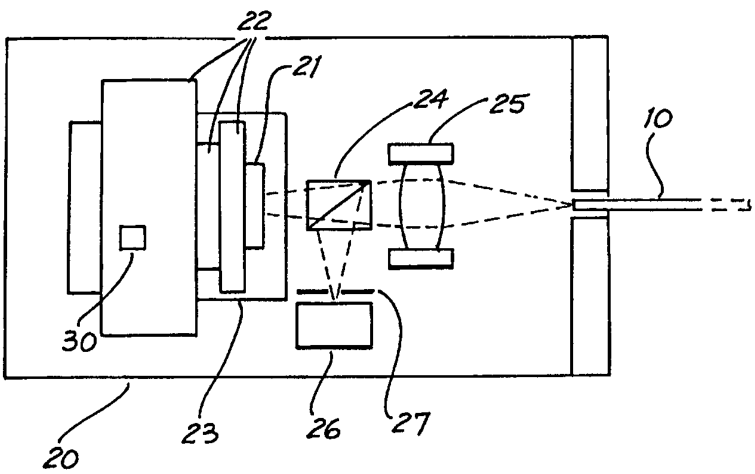
(72) Inventors; and
(75) Inventors/Applicants (*for US only*): HAMMON, Timothy [AU/AU]; (AU). STOKES, Anthony [AU/AU]; The University of Sydney, Dept. of Electrical Engineering, Parramatta Road, Sydney, NSW 2006 (AU).

(74) Agent: GRIFFITH HACK & CO.; G.P.O. Box 4164, Sydney, NSW 2001 (AU).

(81) Designated States: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: OPTICAL FIBRE FILTER SENSOR



(57) Abstract

The magnitude of a physical quantity, typically temperature, is measured by launching light from a light source (21) into an optical fibre (10) that incorporates an optical filter (16) in the form of an in-fibre Bragg grating. The operating temperature of the light source (21) is controlled by a thermoelectric regulator (23) and in a manner cyclically to vary the centre wavelength of the spectrum of light emitted by the source (21) to cover a substantial portion at least of the rejection bandwidth of the optical filter (16). A photodetector (26) is employed for detecting light that is reflected back through the optical fibre (10) and, coupled with a processor (28), for detecting the occurrence of peak reflection. The temperature in the region of the optical filter (16) is determined by reference to the operating temperature of the light source (21) when light is emitted that gives rise to the peak reflection. The measurement of temperature, or other physical quantity that has the potential to influence the reflectance of the optical filter (16), does not require a determination to be made of the complete reflection characteristics of the filter (16). Nor is a measure required to be made of the actual centre wavelength at which peak reflection occurs. Detection is made for the occurrence of the peak reflection and a determination is then made as to the magnitude of the temperature, or other physical quantity, by reference to control exercised over the light source (21).

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Burkina Faso	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgystan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic			SE	Sweden
CG	Congo	KR	Republic of Korea	SG	Singapore
CH	Switzerland	KZ	Kazakhstan	SI	Slovenia
CI	Côte d'Ivoire	LI	Liechtenstein	SK	Slovakia
CM	Cameroon	LK	Sri Lanka	SN	Senegal
CN	China	LR	Liberia	SZ	Swaziland
CS	Czechoslovakia	LT	Lithuania	TD	Chad
CZ	Czech Republic	LU	Luxembourg	TG	Togo
DE	Germany	LV	Latvia	TJ	Tajikistan
DK	Denmark	MC	Monaco	TT	Trinidad and Tobago
EE	Estonia	MD	Republic of Moldova	UA	Ukraine
ES	Spain	MG	Madagascar	UG	Uganda
FI	Finland	ML	Mali	US	United States of America
FR	France	MN	Mongolia	UZ	Uzbekistan
GA	Gabon	MR	Mauritania	VN	Viet Nam

OPTICAL FIBRE FILTER SENSOR

FIELD OF THE INVENTION

This invention relates to a method of and apparatus for use in measuring the magnitude of a physical quantity that has the potential to influence the reflectance of an optical filter. The invention has particular application to the measurement of temperature in inaccessible locations and is hereinafter described in such context. However, it will be understood that the invention does have broader application, to the measurement of any condition that has the potential to induce a change in the reflectance of an optical filter, for example by inducing stress or strain within the optical filter.

BACKGROUND OF THE INVENTION

Various systems have been developed or proposed which incorporate optical fibre sensors and which utilise the spectral response of optical filters to determine the magnitude of physical quantities. By way of example, United States Patents numbered 4,806,012 and 4,996,419 disclose systems which employ filters in the form of in-fibre Bragg gratings and which are suitable for use in measurement of temperature and strain in high voltage, corrosive or constricted environments. However, most of the prior art arrangements are inherently expensive in that, for example, they require the use of elaborate light source systems and optical spectrum analysers. Other prior art arrangements exhibit unsatisfactory long term reliability.

The present invention has been developed from an initial requirement of the electrical power industry for a relatively low cost apparatus that is suitable for use in measuring the temperature in electrical equipment, including in the core of high voltage transformers. Whilst it might be appropriate to use expensive measuring apparatus, such as those incorporating optical spectrum analysers, in conjunction with expensive equipment in power generating stations, the same type of measuring apparatus cannot justifiably be used in relation to relatively inexpensive equipment, such as transformers, where temperature monitoring may be desired for the purpose of determining the effect of load current on the lifetime of the equipment.

The present invention seeks to meet the need for an apparatus that may be employed for effecting measurement of the types above discussed and which has cost compatibility with equipment in relation to which the apparatus is to be used.

SUMMARY OF THE INVENTION

The present invention may be defined broadly in terms of an apparatus for measuring the magnitude of a physical quantity that has the potential to influence the reflectance of an optical filter. The apparatus comprises an optical fibre, at least one optical filter located in or coupled to the optical fibre, a light source arranged to launch light into the optical fibre, and control means for controlling the light source in a manner to vary the centre wavelength of the spectrum of light emitted by the source over a range which embraces a substantial portion at least of the expected spectral response of the or each filter. Also, the apparatus includes means for detecting light reflected back through the optical fibre by the or each filter, for detecting the occurrence of peak reflection and for determining a measure of the physical quantity that exists at the or each filter by reference a condition that is controlled by the control means when light is emitted that gives rise to the peak reflection.

Expressed in an alternative way, the invention may be defined as a method of measuring the magnitude of a physical quantity that has the potential to influence the reflectance of an optical filter. The method comprises the steps of launching light into an optical fibre that incorporates or is coupled to at least one optical filter, controlling the light source in a manner to vary the centre wavelength of the spectrum of light emitted by the source over a range which embraces a substantial portion at least of the expected spectral response of the or each filter, detecting light reflected back through the optical fibre by the or each filter, detecting for the occurrence of peak reflection and determining a measure of the physical quantity that exists at the or each filter by reference to a condition that is controlled by the control means when light is emitted that gives rise to the peak reflection.

The invention as above defined does not require a determination to be made of the complete reflection characteristics of the filter or, if more than one filter is employed, of each of the filters. Nor does the invention require a measure to be made of the actual centre wavelength at which peak reflection occurs. Rather, detection is made for the occurrence of peak reflection and a determination is made as to the magnitude of the physical quantity (that determines the spectral position of the peak reflection) by reference to the control condition exercised over the light source. Thus, the or each filter effectively is illuminated by scanning the light source through a spectrum that covers the expected spectral response of the filter(s). When the spectrum of the light source overlaps with the spectrum of the filter, or with that of each of the filters in turn, light is reflected back along the optical fibre to a detector. The detector provides an output signal which rises as the light source spectrum shifts to match that of the or each filter and which peaks when maximum overlap is achieved.

Since a full spectral characterisation of the filter is not needed, this approach permits the employment of a relatively inexpensive, conventional type of laser diode as the light source and provides for detection by use of a simple photodiode.

PREFERRED FEATURES OF THE INVENTION

When employed in the measurement of temperature, the optical fibre will be positioned to locate the optical filter at a point of interest or to locate each of the optical filters at respective points at which measurements are to be taken. As is well understood, any change in the temperature of the filter will cause a corresponding shift in the spectral response of the filter and, knowing how the centre wavelength of the spectral response relates to temperature in a given filter, a prevailing temperature may be determined by reference to a control condition that exists when peak reflection of the filter is detected. The light source may be controlled by a variable temperature heat source to emit a light spectrum whose centre wavelength varies (in time) with temperature, and the condition of the filter may be correlated with the temperature of the heat source, when the maximum reflection occurs, to determine the prevailing temperature of the filter.

The or each filter preferably comprises an in-fibre Bragg grating, and where more than one filter is required to be located within a single length of the optical fibre each grating will be formed to provide a different spectral response in order that discrimination might be made between sensing points. When single-point sensing is required the filter may be formed as a multilayer-dielectric-stack interference filter having alternating high and low refractive index layers vapour-deposited on a polished endface of the fibre.

The invention will be more fully understood from the following description of a preferred embodiment of an apparatus that is suitable for use in measuring and providing indication of the temperature that exists in an inaccessible location. The description is provided with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings -

Figure 1 shows a block diagrammatic representation of the complete apparatus,

Figure 2 shows an enlarged view of a sensor portion of the apparatus,

Figure 3 shows a diagrammatic representation of optical components of the apparatus,

Figure 4 shows a diagrammatic representation of electrical control/processing components of the apparatus,

Figure 5 shows a graph of a photodetector response and the temperature appropriate to control scanning of the light source, and

Figure 6 shows a graph of the light source temperature against temperature of a typical in-fibre grating.

DETAILED DESCRIPTION OF ONE MODE OF THE INVENTION

As illustrated, the apparatus comprises a length of optical fibre 10 which connects an opto-electronic portion 11 of the apparatus to a location 12 where temperature is to be measured. A display screen 13 is coupled to the portion 11 of the apparatus for providing a visual display of recorded temperature.

The end region 14 of the optical fibre 10 that is positioned in the temperature measuring location 12 incorporates a sensor 15 which is illustrated in Figure 2 and which comprises an in-fibre Bragg grating 16. The end region 14 of the optical fibre is exposed to a window, for example, in the form of a glass tube 15. But for the end region 14, the optical fibre is contained within and protected by a plastics material sleeve 18, and the full length of optical fibre is contained within a heat resistant sleeve 19 composed of polytetrafluoroethylene.

The sleeve 19 or a plurality of such sleeves may be located permanently within a piece of equipment, such as an electrical power transformer, and the or each of the sleeves may be positioned to extend from a gland to a zone at which temperature measurements may be required. Then, at a time when a temperature measurement is required to be made, the optical fibre 10 will be inserted into the sleeve to an extent such that the end region 14 locates in the zone at which the temperature measurement is to be made. This arrangement permits the use periodically of a single apparatus in conjunction with multiple pieces of equipment or, if the apparatus is to be mounted permanently in place in a given piece of equipment, the arrangement will permit replacement or upgrading of the apparatus.

The optical fibre 10 may comprise any photosensitive single mode fibre having the usual core and cladding, and the Bragg grating is formed by interferometrically side-writing the grating into the fibre using UV radiation. The technique employed in this process is well understood and does not form a part of the present invention. However, it has been found that by apodising the grating spectrum, ripples from side band reflections is minimised. The grating 16 is formed to provide a predetermined spectral response and one whose centre wavelength shifts with changes in temperature to which the end region 14 of the fibre is exposed. The spectral response of the Bragg grating will also vary with changes in strain induced in the grating and it is for this reason that the end region 14 of the optical fibre is located within the glass tubing, to isolate the grating from any strain-inducing conditions.

In other applications of the invention, for example when the magnitude of strain is to be measured at a specific site in a piece of equipment, the optical fibre will be chosen to exhibit strain-dependent reflectance variation. To avoid temperature change influences, the optical fibre may be selected as one which does not exhibit a temperature-dependent reflectance variation. Alternatively, compensating optics may be employed to negate the effect of any temperature variations.

The optical fibre 10 is coupled to an optical system 20 which is shown in Figure 3 and which forms a part of the opto-electronic portion 11 of the apparatus. The optical system 20 includes a multi-longitudinal-mode, gain-guided semiconductor laser diode 21 which is mounted within a metal block 22, such as one formed from aluminium or copper. The metal block has minimal thermal mass and, thus, responds quickly throughout its volume to any change in temperature. Also, the metal block 22 which mounts the laser diode 21 is mounted to a Peltier effect thermoelectric temperature regulator 23.

The temperature regulator 23 is driven by a square wave current, having equal high and low periods of approximately 30 seconds, and this causes a substantially triangular-wave temperature cycling of the laser diode 21 at the periodic rate of the current supply to the temperature regulator 23. The gain-guided laser diode 21 is selected to provide a substantially linear temperature-wavelength response, the temperature regulator 23 is employed to control the laser diode 21 in a manner to vary the centre wavelength of the spectrum of light emitted by the laser diode to cover the full width of the spectral response of the grating 16. It is observed that "mode-hopping" of the laser diode should be suppressed in the interest of obtaining a linear temperature-wavelength response over a reasonable range, and this may be achieved by driving the laser with a stable injection current just above that required to establish the lasing threshold. This has the effect of distributing the optical power among many longitudinal modes and allows for smooth transfer of power between modes as the temperature is cycled.

The light emitted from the laser diode is directed through an optical coupler such as a frustrated total internal reflection (FTIR) beam-splitter cube 24 as illustrated in the drawings. One-half of the emitted light is reflected away from the various components of the optical system and the remaining 50% of the emitted light is directed through a focusing lens 25. The light-receiving end of the optical fibre 10 is positioned at the focal point of the lens 25 and, thus, light emitted by the laser diode 21 is launched into the optical fibre.

Transmitted light which has a wavelength remote from the centre wavelength of the grating (i.e., significantly different from the Bragg wavelength) passes through and beyond the grating. However, light which is reflected by the grating 16 at the end region 14 of the optical fibre 10 is reflected in the reverse direction, back along the optical fibre and through the lens 25 and beam splitter 24. In passing through the beam splitter 23, 50% of the reflected light is deflected through 90° to impinge on a photodetector (i.e., a photodiode) 26. The reflected light is focused to a waist adjacent the photodetector, and a pinhole aperture 27 is located immediately in front of the photodetector for the purpose of masking any stray background light.

As will be understood from the previous description, the grating spectrum is effectively interrogated by scanning (i.e., varying) the centre wavelength of the spectrum of the light emitted by the laser diode 21 to cover a substantial portion at least of the rejection bandwidth of the grating, and the reflected light is detected by the photodetector 26 for the purpose of determining when peak reflectance occurs and, thus, when a centre wavelength is emitted which corresponds with the Bragg wavelength of the grating at a given temperature.

A processor 28 is employed to track the reflection of the grating and to identify peak reflectance during each scan cycle. The processor 28 is illustrated in Figure 4 and is connected to the optical system 20 by way of an electrical interface 29.

A measure of the wavelength of the peak reflection is derived by monitoring the temperature of the laser diode 21 using a thermistor 30 which is positioned adjacent and coupled thermally to the copper block 22 that mounts the laser diode 21.

As indicated in Figure 4, the processor 28 receives signals representative of the instantaneous temperature of the laser diode 21 and the output from the photodetector 26, the former being derived from the thermistor 30 and the latter representing the instantaneous temperature of the grating 16. The processor 28 simultaneously reads the two signals through an analogue-to-digital converter, the signals are analysed and processed, and a measured temperature output is displayed.

As also indicated in Figure 4, two external electrical circuits are employed in addition to the processor 28. One of these circuits comprises a laser current control circuit 31 which provides stable injection current for the laser 21 and the other circuit, which is controlled by an output from the processor 28, is a regulator drive circuit 32 which provides the necessary current to drive the temperature regulator 23.

A graph of a typical laser diode operating temperature signal and photodetector signal received in respect of a heating portion of a temperature scan cycle is shown in Figure 5. The processor 28 is employed to acquire and build an array for a predetermined temperature range, for example an array of 2,000 points for a measured temperature range of 200°C. The processor 28 is employed to locate the index of the maximum element value of the photodetector signal array and it then finds the corresponding element value of the laser diode temperature at the same array index. This value is used in the final scaling of the measured temperature.

A typical curve of the laser diode operating, temperature when measured at the peak of the photodetector signal and when compared with the grating temperature, is shown in Figure 6. As may be determined from the curve, the slope indicates a gain of approximately 30 and, in the processor, when the zero-point offset is subtracted from the measured laser diode temperature at the peak of the photodetector signal, the resultant laser diode temperature is multiplied by the gain factor. This product then represents the scaled measured temperature of the grating at the time when the peak reflectance occurs during a given scan cycle.

In a variation of the above described arrangement and in a (non-illustrated) form of the invention which provides for self-regulation against lack of stability, two substantially identical gratings may be employed. One grating is exposed to monitored ambient temperature and, thus, provides a reflectance peak at a centre wavelength which is shifted relative to that which is exhibited by the filter which is exposed to the "unknown" temperature.

A measure of the "unknown" temperature is then obtained by determining the difference between the laser operating temperatures at which the respective peaks occur and by then multiplying the resultant value by the gain factor which, as previously mentioned, is derived as the slope of the curve shown in Figure 6.

In a further variation of the illustrated arrangement of the invention, the forward voltage of the laser diode 21 may be employed in lieu of the thermistor voltage as a measure of the junction temperature. The instantaneous forward voltage is determined by the junction temperature when current is flowing to create laser emission and, thus, the voltage provides a measure of the junction temperature.

CLAIMS

1. An apparatus for measuring the magnitude of a physical quantity that has the potential to influence the reflectance of an optical filter, the apparatus comprising an optical fibre, at least one optical filter located optically in circuit with the optical fibre, a light source arranged to launch light into the optical fibre, control means for controlling the light source in a manner to vary the centre wavelength of the spectrum of light emitted by the source over a range which embraces a substantial portion at least of the expected spectral response of the or each filter, means for detecting light reflected back through the optical fibre by the or each filter, and means for detecting the occurrence of peak reflection and for determining a measure of the physical quantity that exists at the or each filter by reference to a condition that is controlled by the control means when light is emitted that gives rise to the peak reflection.

2. The apparatus as claimed in claim 1 wherein the optical fibre is formed at spaced intervals along its length with a plurality of optical filters in the form of in-fibre Bragg gratings and wherein each grating is formed to exhibit a unique spectral response.

3. The apparatus as claimed in claim 1 wherein the optical fibre is formed at one position only with an optical filter in the form of an in-fibre Bragg grating.

4. The apparatus as claimed in claim 3 wherein the optical filter is located adjacent the end of the optical fibre which is remote from the light source.

5. The apparatus as claimed in claim 1 wherein the optical fibre is provided at its end which is remote from the light source with a single optical filter in the form of a multi-layer dielectric-stack-interference filter, the filter having alternating high and low refractive index layers deposited on an end face of the optical fibre.

6. The apparatus as claimed in any one of the

preceding claims wherein the control means functions cyclically to vary the operating temperature of the light source in a manner to vary the centre wavelength of the spectrum of light emitted by the light source.

7. The apparatus as claimed in claim 6 wherein the light source comprises a gain-guided semiconductor laser diode.

8. The apparatus as claimed in claim 7 wherein the light source is mounted to a thermoelectric temperature regulator.

9. The apparatus as claimed in claim 8 wherein the thermoelectric temperature regulator is driven by a current having a square waveform.

10. The apparatus as claimed in any one of claims 6 to 9 and including processing means for generating a measure of the physical quantity as a function of the temperature of the light source when light is emitted that gives rise to the peak reflection.

11. The apparatus as claimed in any one of claims 7 to 9 and including processing means for generating a measure of the physical quantity as a function of the forward voltage of the laser diode when light is emitted that gives rise to the peak reflection.

12. The apparatus as claimed in claim 10 or claim 11 wherein the processing means is arranged to track reflection of the or each optical filter and to identify peak reflection during each cycle of the control means.

13. The apparatus as claimed in any one of the preceding claims wherein the means for detecting the reflected light comprises a photodetector which is located optically in circuit with the optical fibre by a beam splitter.

14. A temperature measuring apparatus comprising an optical fibre, at least one optical filter located optically in circuit with the optical fibre and arranged to be positioned in a region where temperature is to be measured, a light source arranged to launch light into the optical fibre, means for controlling the temperature

of the light source in a manner cyclically to vary the centre wavelength of the spectrum of light emitted by the source to cover a substantial portion at least of the rejection band width of the or each filter, means for detecting light reflected back through the optical fibre by the or each filter, and means for detecting the occurrence of peak reflection and for determining the temperature in the region of the or each filter by reference to the operating temperature of the light source when light is emitted that gives rise to the peak reflection.

15. A method of measuring the magnitude of a physical quantity that has the potential to influence the reflectance of an optical filter, the method comprising the steps of launching light into an optical fibre that incorporates or is coupled to at least one optical filter, controlling the light source in a manner to vary the centre wavelength of the spectrum of light emitted by the source over a range which embraces a substantial portion at least of the expected spectral response of the or each filter, detecting light that is reflected back through the optical fibre by the or each filter, detecting for the occurrence of peak reflection and determining a measure of the physical quantity that exists at the or each filter by reference to a condition that is controlled by the control means when light is emitted that gives rise to the peak reflection.

16. The method as claimed in claim 15 wherein the light source is controlled in a manner such that its operating temperature is varied cyclically in a manner to vary cyclically the centre wavelength of the spectrum of light emitted by the light source.

17. The method as claimed in claim 16 wherein the measure of the physical quantity that exists at the or each filter is determined as a function of the temperature of the light source when light is emitted that gives rise to the peak reflection.

18. The method as claimed in claim 17 wherein the

light source comprises a gain-guided semiconductor laser diode and wherein the temperature of the light source is determined by reference to the forward voltage of the light source when light is emitted that gives rise to the peak reflection.

19. A method of measuring temperature and which comprises the steps of launching light into an optical fibre that incorporates at least one optical filter, controlling the temperature of the light source in a manner cyclically to vary the centre wavelength of the spectrum of light emitted by the source to cover a substantial portion at least of the rejection bandwidth of the or each filter, detecting light reflected back through the optical fibre by the or each filter, detecting for the occurrence of peak reflection and determining a measure of the temperature that exists in the region of the or each filter by reference to the operating temperature of the light source when light is emitted that gives rise to the peak reflection.

20. An apparatus for measuring temperature, substantially as shown in the accompanying drawings and substantially as hereinbefore described with reference thereto.

21. A method of measuring temperature, substantially as hereinbefore described with reference to the accompanying drawings.

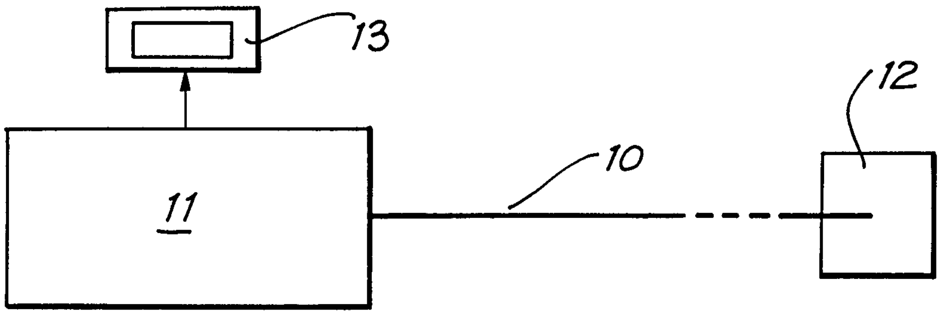


FIG. 1

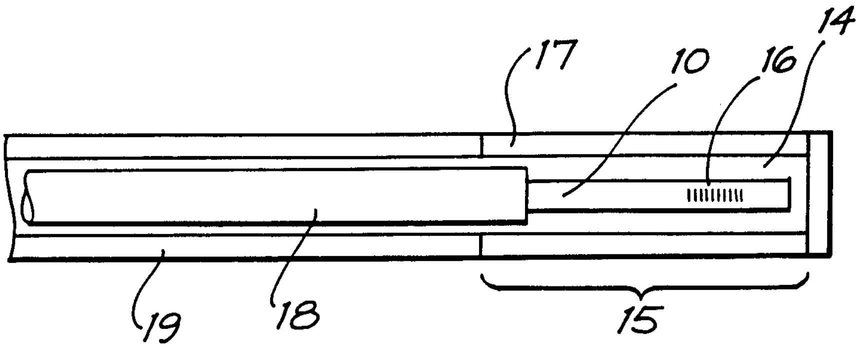


FIG. 2

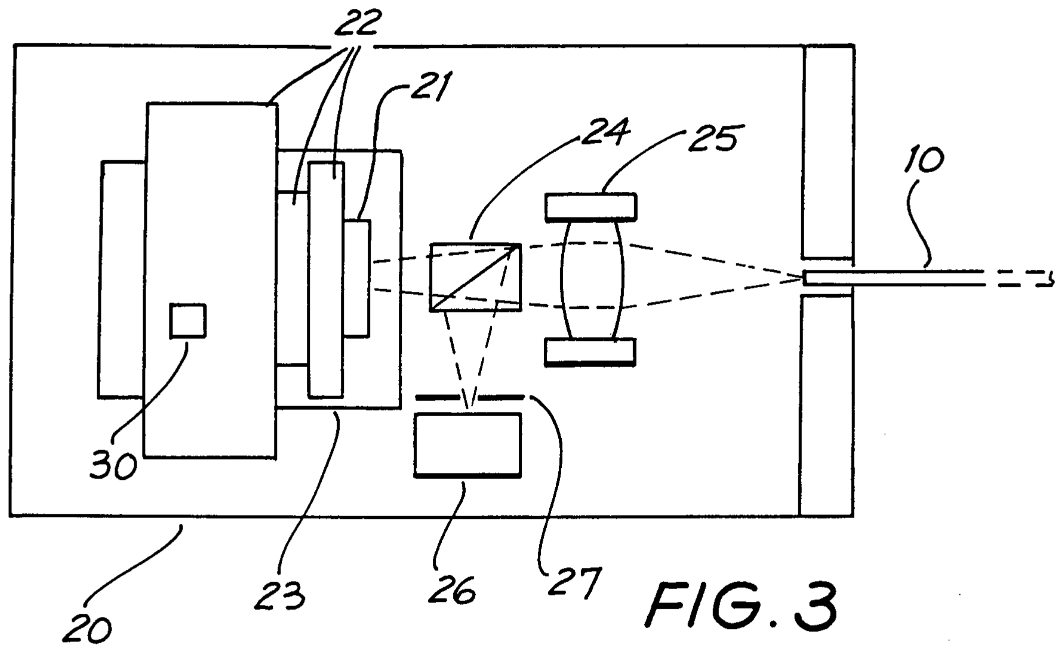


FIG. 3

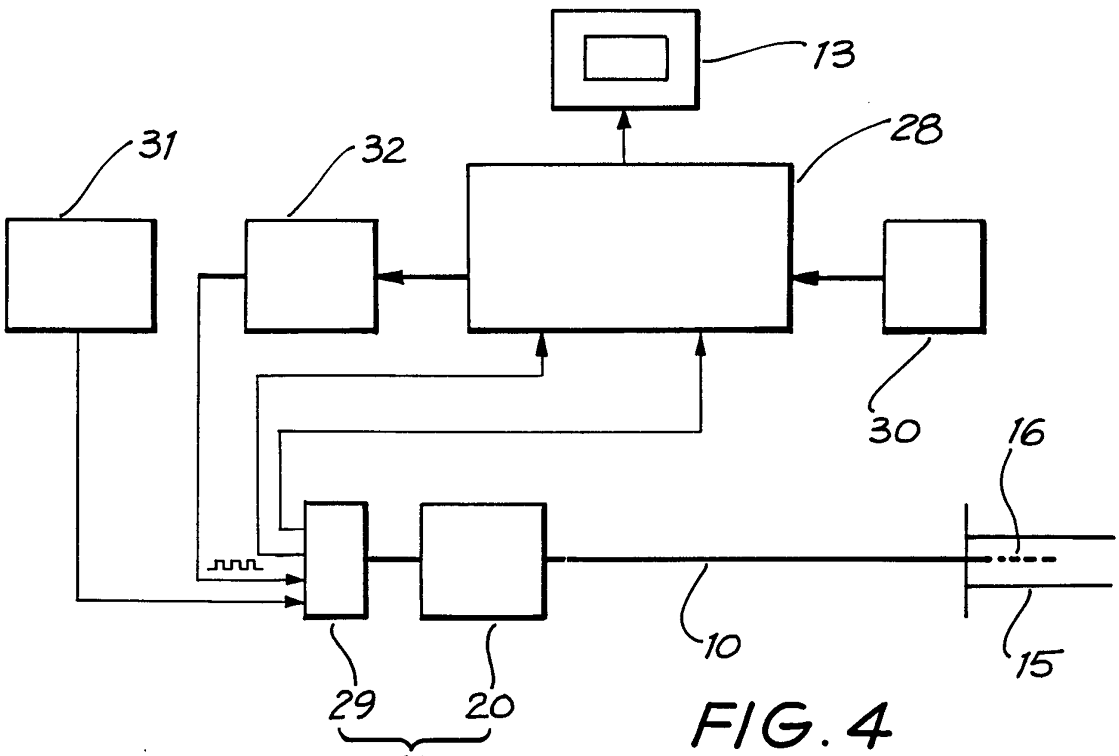


FIG. 4

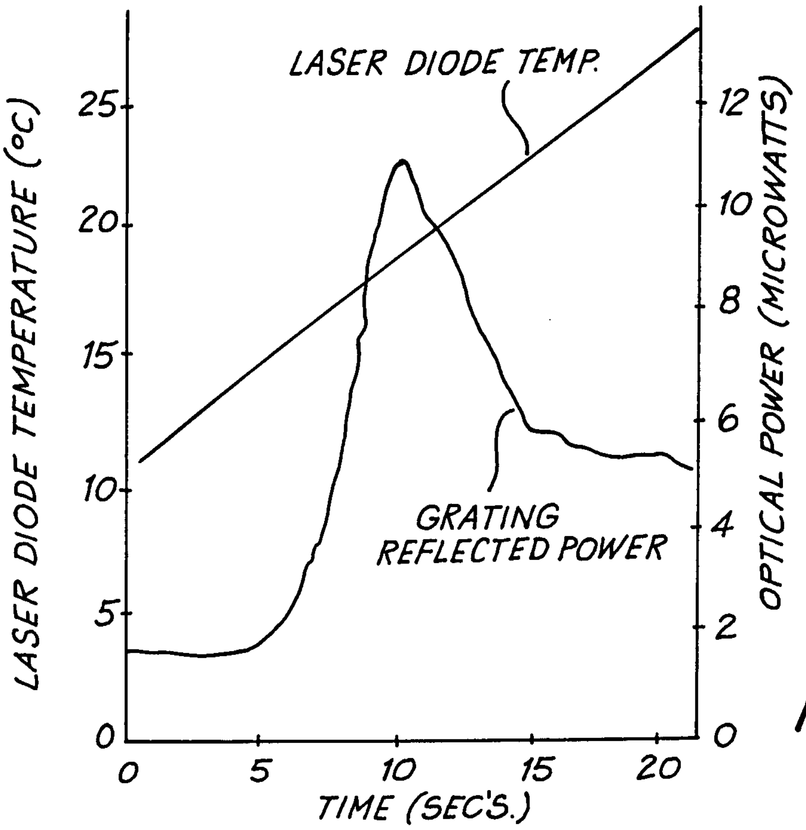

LASER DIODE TEMP.
GRATING REFLECTED POWER
LASER DIODE TEMPERATURE (°C)
OPTICAL POWER (MICROWATTS)
TIME (SEC'S.)
0
5
10
15
20
25
0
2
4
6
8
10
12
0
5
10
15
20

FIG.5

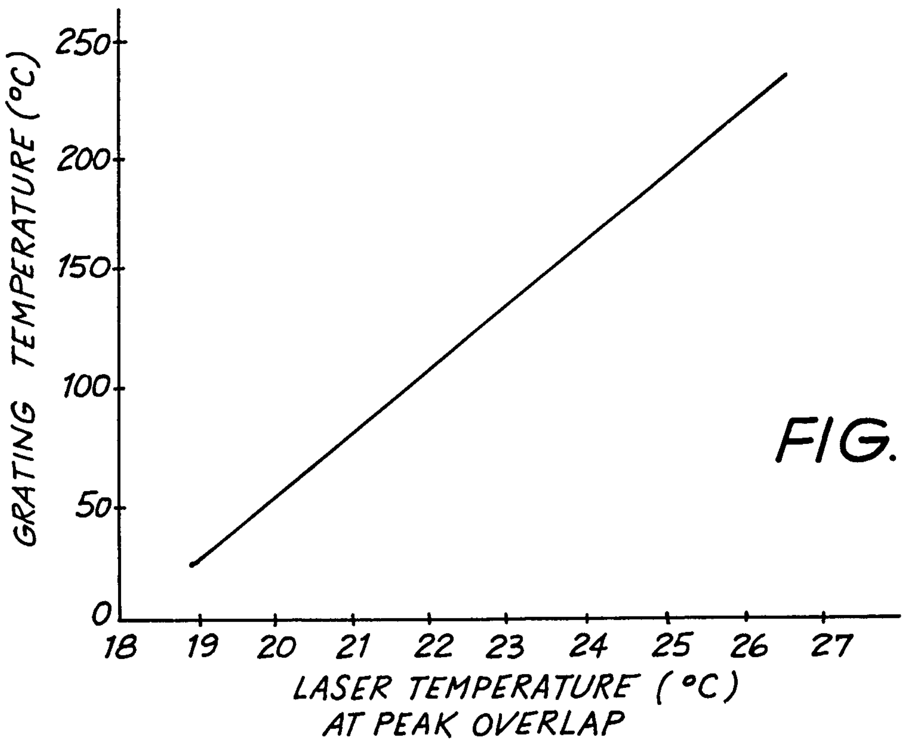

GRATING TEMPERATURE (°C)
LASER TEMPERATURE (°C) AT PEAK OVERLAP
0
50
100
150
200
250
18
19
20
21
22
23
24
25
26
27

FIG.6

INTERNATIONAL SEARCH REPORT

.ternational Application No.
PCT/AU 96/00293

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: A61B 5/02; G01J 5/08; G01K 11/00, 11/32; G01L 11/02; G02B 6/00

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: A61B 5/02; G01J 5/08; G01K 11/00, 11/32; G01L 11/02, G02B 6/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
DERWENT: optic; fibre; filter; reflect; measur/detect/test/determine;
JAPIO: optic; fibre; filter; reflect; measur/detect/test/determine;

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 89/10087 A (MEDEX) 2 November 1989 Whole document	1,4,13-15, 19
X	WO 86/01286 A (UNITED TECHNOLOGIES CORPORATION) 27 February 1986 Whole document	1,2,13-15, 19
X	US 5345519 A (ZHUO) 6 September 1994 whole document	1,4,13-15, 19

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

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

Date of the actual completion of the international search	Date of mailing of the international search report
14 June 1996	25TH JUNE 1996.

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (06) 285 3929	F.C. PEARSON Telephone No.: (06) 283 2195

C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4924870 A (WLODAREXYK) 15 May 1990 Whole document	1,4,13-15, 19
X	US 4430565 A (BROGARDH) 7 February 1984 Whole document	1,4,13-15, 19
X	EP 0528657 A (FIBEROPTIC SENSOR TECHNOLOGIES) 24 February 1993 Whole document	1,4,13-15, 19
A	EP 0216565 A (PLESSEY OVERSEAS LTD) 1 April 1987 Whole document	
A	EP 0210719 A (ADVANCED FIBEROPTICS TECHNOLOGIES) 4 February 1987 Whole document	

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.
PCT/AU 96/00293

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

Patent Document Cited in Search Report		Patent Family Member					
US	4430565	DE	3136448	JP	57087000	SE	8006679
WO	8910087	CA	1320355	EP	411054	US	4883062
WO	8601286	EP	192659	US	4761073	US	4806012
US	5345519	CA	2105605				
EP	528657	CA	2068033	JP	5196528	US	5275053
		US	5385053				
EP	216565	AU	62476/86	CA	1272625	JP	62111212
		NZ	217520	US	4795226		
EP	210719	JP	61275627	US	4689483		

END OF ANNEX