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D E C I S I O N
of 24 June 2004

Case Number: T 0096/00 - 3.4.2

Application Number: 94916625.0

Publication Number: 0696348

IPC: G01C 19/72

Language of the proceedings: EN

Title of invention:
Rapid turn-on source for fiber optic gyroscope

Patentee:
HONEYWELL INC.

Opponent:
LITEF GmbH

Headword:
-

Relevant legal provisions:
EPC Art. 52(1), 54, 56, 111(1), 114

Keyword:
"Admissibility of documents filed during appeal proceedings (yes) - no remittal"
"Novelty (yes)"
"Inventive step (yes)"

Decisions cited:
T 0416/87

Catchword:
-

Case Number: T 0096/00 - 3.4.2

D E C I S I O N
of the Technical Board of Appeal 3.4.2
of 24 June 2004

Appellant: (Opponent)	LITEF GmbH Lörracher Str. 18 D-79115 Freiburg i. Br. (DE)
Representative:	Müller -Hoffmann & Partner Patentanwälte Innere Wiener Strasse 17 D-81667 München (DE)
Respondent: (Proprietor of the patent)	HONEYWELL INC. Honeywell Plaza Minneapolis Minnesota 55408 (US)
Representative:	Fox-Male, Nicholas Vincent Humbert Eric Potter Clarkson Park View House 58 The Ropewalk Nottingham NG1 5DD (GB)
Decision under appeal:	**Interlocutory decision of the Opposition Division of the European Patent Office posted 16 October 2000 concerning maintenance of European patent No. 0696348 in amended form.**

Composition of the Board:

Chairman: A. G. Klein
Members: F. J. Narganes-Quijano
M. J. Vogel

Summary of Facts and Submissions

I. The appellant (opponent) has appealed against the interlocutory decision of the opposition division finding European patent No. 0 696 348 (based on European patent application No. 94916625.0) as amended during the first-instance proceedings to meet the requirements of the EPC.

The opposition filed by the appellant against the patent as a whole was initially based on the grounds of lack of inventive step (Article 100(a) together with Articles 52(1) and 56 EPC), and the grounds of lack of novelty (Article 100(a) together with Articles 52(1) and 54 EPC) were subsequently introduced by the opposition division into the proceedings.

In its decision the opposition division held in particular that the subject-matter of independent claims 1 and 9 as amended was novel and involved an inventive step (Articles 52(1), 54 and 56 EPC) with regard to the disclosure of documents

D1 : US-A-5024535

D2 : US-A-5018154.

II. During the appeal proceedings the appellant submitted the following documents:

D3 : JP-A-3-92734 and English language translation

D4 : DE-C-4037118

D5 : GB-A-2157425.

III. Oral proceedings were held before the Board on 24 June 2004 in the presence of the parties.

The appellant requested setting aside of the decision and the revocation of the patent in its entirety.

The respondent (patent proprietor) requested that the appeal be dismissed and the patent be maintained as amended before the opposition division.

At the end of the oral proceedings the Board gave its decision.

IV. The patent as amended according to the interlocutory decision under appeal includes claims 1 to 11, the independent claims 1 and 9 reading as follows:

"1. A light source apparatus for a fiber optic rotation sensor (10), said apparatus comprising:

(a) a light source (14) to provide light for input to the fiber optic rotation sensor (10);

(b) source control means (16) for generating a source control signal representative of a temperature of said light source (14);

(c) means (32) for generating one of a plurality of scale factors for the fiber optic rotation sensor (10) as a function of said light source control signal over a predetermined temperature range;

wherein said source control means (16) includes:

(d) a temperature sensor (120) providing a current signal representative of said temperature of said light source (14);

(e) a buffer network (122) for sinking said current signal and for generating a source control voltage as said source control signal; and

(f) drive means (42) connected to said light source (14) and to said buffer network (122) for generating a drive signal as a function of said source control signal to drive said light source (14)."

"9. A method of light source wavelength compensation for a fiber optic rotation sensor (10), comprising the steps of:
providing a light source (14);
sensing a temperature of said light source (14) and generating a source control signal representative thereof;
applying a drive signal to said light source (14) as a function of said source control signal;
generating a scale factor for said fiber optic rotation sensor (10) as a function of said source control signal;
wherein said temperature-sensing and source control signal generating step includes the steps of:
generating a current signal representative of the temperature of said light source (14);
sinking said current signal into a buffer network (122) through a first selected impedance; and
generating a source control voltage as said source control signal as a function of said voltage across said first selected impedance and a selected voltage of said buffer network (122)."

V. The arguments of the appellant in support of its requests can be summarized as follows:

Document D1 not only discloses the correction of the scale factor of a fibre optic gyroscope on the basis of the dependency of the wavelength of the light emitted by a semiconductor laser on the temperature of the laser, but also the control of the temperature of the laser by means of the injection current (column 5, lines 19 to 26). In addition, the control operation carried out by the control circuit (Figure 1) requires a buffer network as defined in the patent.

Document D2 teaches to adjust the injection current applied to a semiconductor laser according to the temperature of the laser. In particular, the slope efficiency - which defines the proportionality between current and output power above the laser threshold and is independent of any modulation (Figures 3 and 4, and equation (7)) - is controlled according to the laser temperature, the slope efficiency being the same parameter that is controlled in the contested patent.

Document D3 discloses a laser diode the output power of which is monitored by a photo-receiving sensor. According to the document the output power and the temperature of the laser diode are linked by a predetermined function, and consequently monitoring the output power is equivalent to monitoring the temperature of the laser diode. Thus, the intensity measured by the sensor is directly linked to the temperature of the laser diode and therefore the sensor is, or operates as, or at least replaces a light source temperature sensor (page 3, lines 27 and 28, and page 5, lines 26 to 29 of the English translation). The document not only discloses stabilization of the laser power, but also the correction of the scale factor according to the temperature information derived from the laser current.

Document D4 discloses a fibre optic gyroscope in which the central wavelength of the semiconductor laser is controlled for correcting variations in the scale factor. The temperature of the laser is monitored according to the detected intensity for controlling the injection current of the laser so as to maintain constant the optical coupling ratios of the gyroscope and to minimize variations in the scale factor.

Document D5 discloses the correction of the scale factor by influencing the laser light source according to a control signal generated by a temperature compensation circuit as a function of the operating temperature measured by means of a thermocouple, the control signal adjusting the bias current of the light source and therefore the laser wavelength so as to correct the variations in the scale factor. Although reference is made to the ambient temperature, the document also teaches that "changes of the temperature of the laser diode itself" must be compensated (page 2, lines 49 to 58), and since the temperature sensor at the coil is in thermal contact with the light source, the sensor characterizes the temperature of both the coil and the light source, the document itself proposing the use of additional temperature sensors for generating a more accurate composite temperature measurement (page 3, lines 20 to 25). Furthermore, the scale factor is corrected and not simply stabilized, the compensation calculation of the scale factor according to the temperature variations being nothing else than the determination of a plurality of scale factors, each possible temperature value being correlated to a scale factor (page 1, lines 30 to 38). In addition, the skilled person would recognise that a constant power substantially provides a constant wavelength.

Thus, the claimed subject-matter is anticipated by any of documents D1, D3, D4 and D5. In any case, the claimed subject-matter is rendered obvious by the teaching of the documents, in particular by the combination of documents D1 and D2, and also by the teaching of document D3, the patent specification itself acknowledging as prior art the dependency of the output of the laser source on the temperature and the light source drive current (page 2, lines 17 to 19, and page 3, lines 40 to 43).

VI. The arguments of the respondent are essentially the following:

Document D1 discloses scale factor correction, and alternatively controlling the temperature of the laser source, but fails to disclose or suggest using the injection current to control the temperature of the laser. In addition, no buffer network as claimed is disclosed in the document.

Document D2 only discloses temperature compensation of a semiconductor laser for the purpose of maintaining the laser output power constant in modulation devices in which the output power is a prime concern. The document is silent as to scale factor compensation, it does not even address wavelength in any way.

In document D3 the output intensity of the laser diode is maintained constant to counterbalance variations in temperature. However, no temperature derived signal is used for driving the diode. In addition, the scale factor is corrected according to the ambient temperature which is determined independently of any temperature sensor.

In document D4 the temperature of the laser source is varied for the purposes of maintaining constant predetermined coupling ratios of the gyroscope and extracting precise gyro output data. No temperature measurement or temperature derived signal is mentioned.

In document D5 the light source current is controlled to adjust the light source wavelength so as to maintain constant the scale factor.

In addition, while documents D2 to D5 essentially disclose closed-loop control systems ("Regelung"), the invention relates to an open-loop control system ("Steuerung") in which the light source is initially given a low drive value to protect the light source and then values within a predetermined range while the scale factor is being corrected, thus avoiding overstressing the light source and providing an optimal trade-off between performance and light source longevity.

Reasons for the Decision

1. The appeal is admissible.

2. *Documents filed during appeal proceedings*

Documents D3 and D4 were filed by the appellant together with the statement setting out the grounds of appeal and document D5 was filed shortly thereafter. The respondent has contested the admissibility of these documents in view of their late submission and of the irrelevance of their content for the assessment of the case. During the oral proceedings the appellant indicated that the assessment of the content of document D3 might require remittal of the case to the opposition division.

As already noted by the Board in the annex to summons to oral proceedings, the content of documents D3 to D5 is - as will be apparent in the assessment of patentability in points 3 to 5 below - not so relevant in relation to the content of documents D1 and D2 relied upon by the parties during the first-instance proceedings that their admission into the proceedings would justify the remittal of the case. In view of the parties' submissions, and since the parties have extensively commented on the content of these documents during the written and the subsequent oral proceedings, the Board has decided in the circumstances of the case to admit documents D3 to D5 into the proceedings (Article 114 EPC) and to exercise its discretion under Article 111(1) EPC by itself examining the documents and deciding on the case brought forward by the appellant. The Board observes that, in view of the final outcome of the case, the admission of these documents does not result in a situation adverse to the respondent and that, in the absence of any apparent reason that would have prevented the appellant from filing the documents during the first-instance proceedings, depriving the appellant of the opportunity to have the documents considered at two instances is in the present case not unfair to the appellant as the appellant itself is directly responsible for the filing of the documents at this stage of the proceedings (see in this respect T 416/87, OJ EPO 1990, 415, point 9 of the reasons).

3. *Claim 1 - Novelty*

3.1 Document D1 discloses a light source apparatus for a fibre optic gyroscope (Figure 1, and column 1, line 11 *ff*.). The scale factor of the gyroscope depends on the wavelength of the light emitted by laser diode 12, and the wavelength depends in turn on the temperature of the laser diode (column 1, lines 53 to 57, and column 4, line 65 to column 5, line 1). The apparatus includes a laser diode temperature sensor 11 generating a current signal (column 3, lines 23 to 27, and column 5, lines 1 to 8), and control means including a microprocessor 60 and a look-up Table 61 for generating from said current signal a control signal representative of the temperature of the laser diode (column 2, lines 30 to 33, column 4, lines 22 to 64, and column 5, lines 9 to 18). The scale factor is then corrected according to the control signal (column 5, lines 31 to 37), thus generating one of a plurality of scale factors as a function of the temperature of the laser diode over the operational temperature range of the apparatus.

The appellant has submitted that according to the paragraph in column 5, lines 19 to 26 of the document the injection current is used to control the temperature of the laser diode according to the control signal. However, the mentioned paragraph only refers to the use of the control signal to maintain the laser diode at a desired temperature by means of the microprocessor and optionally a suitable control circuit, and none of the remaining passages of the document would allow the conclusion that the temperature of the laser diode is properly controlled by means of the injection current, let alone that the injection current itself is controlled according to the control signal.

Therefore, document D1 fails to disclose means for generating a drive signal for driving the light source according to the control signal representative of the temperature of the light source.

3.2 Document D2 discloses a light modulator for use in an exposure apparatus, the modulator modulating the intensity of the light emitted by a semiconductor laser according to an external modulation signal (Figures 1 and 5, and column 1, lines 5 to 10). The optical output of the semiconductor laser depends on the temperature of the laser (column 1, line 13 to column 2, line 13, and Figures 3 and 4), and this dependency is compensated by the provision of means for correcting the drive current of the laser according to its temperature (column 2, lines 16 to 23, column 3, line 61 to column 4, line 14, and column 7, lines 1 to 14).

The document, however, is silent as to the provision of means for generating a scale factor for a fibre optic rotation sensor, or other wavelength-dependent optical parameter, according to the temperature of the light source.

3.3 Document D3 discloses an optical fibre gyroscope (page 2, lines 8 to 10 of the English translation, and Figure 1) comprising a semiconductor light source and means for correcting variations in the scale factor due to fluctuations in the ambient temperature (page 3, lines 18 to 28). The injection current of the light source is controlled so that the output intensity of the light source being detected by a power monitoring photodiode is maintained constant (page 5, lines 4 to 10, and page 6, line 32 to page 7, line 6); this control operation allows in addition the determination of the temperature of the light source and the subsequent determination of the environmental temperature (page 5, line 11 to page 6, line 29), the latter being then used to correct the scale factor (page 5, lines 23 to 25, page 7, line 33 to page 8, line 1, and page 8, lines 30 and 31).

Although the document mentions a thermocouple (page 6, lines 24 to 26), this element is only used for the experimental determination of the relationship between the environmental temperature and the input current required to maintain constant the output intensity (page 6, lines 11 to 29, page 7, lines 21 to 32, and page 8, lines 2 to 7 and 21 to 24, together with Figure 2), and the document excludes expressly the use of temperature measuring elements such as a thermocouple during the normal control operation of the gyroscope (page 2, lines 10 to 17, page 3, lines 29 to 33, and page 8, lines 26 to 29). Therefore, contrarily to the appellant's contention, document D3 does not anticipate the provision of a temperature sensor as claimed. In addition, while in claim 1 the correction of the scale factor and the driving of the light source are both controlled according to the temperature of the light source, in document D3 these two control operations are carried out according to two parameters which, although interrelated (page 7, first and last paragraphs), are distinct, namely the ambient temperature and the output of the light source, respectively.

3.4 Document D4 discloses a fibre optic gyroscope (Figures 1 and 2) comprising a semiconductor laser and means for counterbalancing the influence of fluctuations in ambient temperature, pressure, etc. on the optical coupling characteristics, and in particular on the scale factor of the gyroscope (column 1, lines 34 to 42, and column 3, line 20 to column 4, line 13). The intensity of the light emitted by the laser is detected together with the intensity of the light at predetermined branches of the optical coupler of the gyroscope (column 2, lines 48 to 65), and the temperature and/or the input current of the laser are then varied so as to adjust the wavelength and the intensity of the light emitted by the laser (column 1, line 43 to column 2, line 9, column 2, lines 27 to 38, column 2, line 66 to column 3, line 8, and column 4, lines 25 to 39).

However, regardless of whether the temperature of the light source is properly monitored according to the detected intensity as submitted by the appellant, no basis can be found in the document for the measurement or the determination of the temperature of the laser source. Therefore, document D4 fails to disclose, among others, means for sensing the temperature of the light source and generating a signal representative thereof.

3.5 Document D5 discloses a fibre optic gyroscope (figure and page 1, lines 5 to 7) comprising a laser diode and sensors arranged to detect the temperature of the gyroscope fibre arrangement and/or the associated optical system of the gyroscope (page 1, lines 48 and 49, page 2, lines 49 to 51, and page 3, lines 8 to 11 and 19 to 25). The current driving the diode is then controlled according to the temperature detected by the sensors so as to adjust the wavelength of the light emitted by the diode, thus compensating the influence of the temperature variations on the scale factor (page 1, lines 30 to 45, and page 2, lines 49 to 53).

Although the document mentions that "some form of control of the laser source will inevitably be required to compensate for changes in temperature of the laser diode itself" (page 2, lines 53 and 54), the document fails to disclose a sensor providing a signal representative of the temperature of the diode. In addition, the document further specifies that the wavelength is changed "to exactly the amount required to give zero scale factor temperature coefficient over the entire operating temperature range of the gyroscope" (page 2, lines 53 to 58), i.e. to maintain constant the scale factor (page 1, lines 33 to 38 and

50 to 53, page 2, lines 37 to 41 and 49 to 51, and page 3, lines 4 to 6). Thus, document D5 does not disclose a temperature sensor as claimed, let alone the generation of a plurality of scale factors as a function of the temperature of the light source.

3.6 Having regard to the above, and regardless of whether any of the documents discloses a buffer network as that of the claimed apparatus, none of documents D1 to D5 anticipates the subject-matter of claim 1 (Articles 52(1) and 54 EPC).

4. *Claim 1 - inventive step*

4.1 Closest prior art

The primary problem addressed in the patent is the correction of the influence of the temperature variations of the light source on the output, and in particular on the scale factor of a rotation sensor (page 2, lines 11 to 19, and page 3, lines 49 to 54). While this problem is also addressed in document D1, document D2 does not relate to fibre optic rotation sensors, but to modulators (point 3.2 above), and documents D3, D4 and D5 do not focus primarily on the temperature variations of the light source itself (points 3.3 to 3.5 above). Consequently, document D1 represents the closest prior art in the assessment of inventive step of the claimed subject-matter according to the problem-solution approach.

4.2 Distinguishing features - objective problem

Assuming for the sake of argument that, as submitted by the appellant, the circuit represented in Figure 1 of document D1 includes, contrary to the respondent's submissions, a buffer network as defined in claim 1, the claimed apparatus differs from that disclosed in document D1 in the provision of means for generating a drive signal for driving the light source according to the control signal representative of the temperature of the light source (point 3.1 above). Thus, while in document D1 the control signal representative of the temperature of the light source is used for correcting the scale factor and/or for controlling the temperature of the light source, according to the claimed subject-matter the influence of the light source temperature variations on the scale factor is compensated not only by correcting the wavelength-dependent scale factor, but also by controlling the driving current of the light source and therefore the wavelength emitted by the light source according to the temperature of the light source. This twofold correction mechanism allows for an accurate temperature compensation of the scale factor under all start-up temperatures of the light source and within the suitable rating limits of the light source circuitry without damaging the light source (page 3, lines 49 to 54, and page 5, lines 39 to 46 of the patent specification, and point VI above).

In view of the technical effects achieved by the claimed subject-matter, and since the same degree of accuracy in temperature compensation of the scale factor appears to be achievable with the light source apparatus of document D1 (document D1, column 5, lines 27 to 37), the objective problem solved by the claimed subject-matter over the disclosure of document D1 can be seen as providing an alternative mechanism of compensation of the influence on the scale factor of the variations in light source temperature without detriment to the light source.

4.3 Assessment of inventive step

Document D2 does not relate to fibre optic rotation sensors or to devices involving a scale factor or other optical wavelength-dependent parameter, but to exposure apparatuses using the light from a semiconductor laser as exposure light and devices for modulating the intensity of the exposure light according to an external modulation signal (point 3.2 above). In addition, the document refers only to the dependency of the threshold value current and of the slope efficiency, and therefore also of the optical output or intensity of the laser on the temperature of the laser (column 1, lines 5 to 20, and column 7, lines 1 to 14); although the control of these parameters inherently affects the wavelength of the light emitted by the laser, the document does not address the specific dependency of the wavelength on the laser temperature, let alone the control of the input current so as to specifically compensate for changes in the wavelength caused by temperature variations of the laser source. Thus, in the Board's view the skilled person would have found no hint in document D2 which would have induced him to incorporate the laser output control means disclosed in the document in the apparatus of document D1 in order to solve the above mentioned problem which inherently addresses the dependency of the scale factor, not on the temperature-dependent output intensity, but on the temperature-dependent wavelength of the light emitted by the light source. In addition, the precise teaching of the document would suggest at the most replacing the temperature compensation arrangement disclosed in document D1 by the optical output correction arrangement of document D2, and the application of the teaching of document D2 to the disclosure of document D1 would therefore not result in the claimed apparatus.

In document D3 the temperature of the light source is determined only for the subsequent determination of the environmental temperature, the scale factor being then corrected according to the latter (point 3.3 above). Therefore, the document does not address the problem formulated above relating to counterbalancing the effects of temperature variations of the light source. In addition, the teaching of the document would suggest at the most driving the light source apparatus of document D1 so as to maintain its output intensity constant (page 7, lines 1 to 4), i.e. would not hint at driving the light source according to the temperature of the same as required by the claimed subject-matter.

In document D4 both the temperature and the input current, and consequently also the wavelength of the laser (column 3, lines 9 to 12), are varied in order to compensate the influence of the variations of the ambient temperature on the optical coupling characteristics, and in particular on the scale factor of the gyroscope (point 3.4 above). Thus, the document does not address the problem formulated above which specifically relates to the temperature variations of the light source. Furthermore, according to document D4 the temperature of the laser source is purposely varied (see point 3.4 above) and this teaching runs counter the main purpose of both document D1 and the present invention, i.e. counterbalancing the effects of the variations of the temperature of the light source, and for this reason the skilled person would have refrained from applying the teaching of document D4 to the apparatus of document D1. In addition, the application of the teaching of document D4 (column 1, lines 34 to 37) to the apparatus of document D1 would result in controlling the temperature and the driving current of the light source so as to compensate any influence of temperature variations on the scale factor, and would therefore not result in the claimed subject-matter in which different scale factors are generated according to the light source temperature.

Document D5 teaches controlling the laser diode driving current, and thus adjusting the laser wavelength, according to the variations in ambient temperature (point 3.5 above) and also according to the variations in diode temperature (page 2, lines 53 and 54). The latter approach, however, involves modifying the control system "in order not only to stabilise the wavelength, but also to bias or change the wavelength at will artificially" (page 2, lines 53 to 56) and would therefore risk overstressing the diode, i.e. would be in detriment to the light source circuitry and therefore at variance with the problem formulated above. In addition, the document teaches consistently to control the diode driving current so as to maintain constant the scale factor (page 2, lines 56 to 58) and the application of the corresponding teaching to the apparatus disclosed in document D1 would therefore result in an apparatus operating with a constant scale factor, i.e. would not result in the claimed subject-matter which requires means for generating one of a plurality of scale factors according to the light source temperature.

According to an alternative line of argument of the appellant, the patent specification acknowledges that it was already known in the prior art that the output of a laser source, and more specifically the wavelength of the emitted light, depends on the temperature and the drive current of the laser source. This prior art knowledge cannot in the Board's view be disputed (see in this respect document D4, column 3, lines 9 to 12). However, as exemplified by the control systems of the prior art documents discussed above, the dependency of the light source output and/or wavelength on drive current and/or light source temperature is at the basis of a large variety of different and non-equivalent control and compensation mechanisms, and knowledge of this dependency alone does not render obvious the specific control and compensation mechanism defined in the claimed subject-matter. In addition, the assessment above shows that only hindsight knowledge of the claimed invention could have suggested applying the teachings of documents D2 to D5 to the apparatus of document D1 in such a way as to arrive at the control and compensation mechanism defined in claim 1.

4.4 Having regard to the above, the subject-matter of claim 1 is not rendered obvious within the meaning of Article 56 EPC by the prior art referred to by the appellant, independently of whether - as disputed by the parties - a buffer network as that of the claimed apparatus is also disclosed in, or rendered obvious by the prior art.

5. *Independent claim 9 and dependent claims*

Claim 9 defines a method of light source wavelength compensation for a fibre optic rotation sensor the steps of which are essentially in one-to-one correspondence with the functional features of the different means of the apparatus defined in claim 1. In addition, the appellant has not advanced any specific submission with regard to this claim other than those considered in connection with claim 1. Consequently, the same conclusions reached in points 3 and 4 above with regard to claim 1 apply to claim 9 (Articles 52(1), 54 and 56 EPC).

Since claims 2 to 8, 10 and 11 are dependent claims, the above conclusions apply equally to these claims.

6. In view of the above, the appellant has not convinced the Board that the patent amended according to the interlocutory decision under appeal and the invention to which it relates do not meet the requirements of the EPC. Consequently, the appeal has to be dismissed.

Order

For these reasons it is decided that:

The appeal is dismissed.

The Registrar: The Chairman:

P. Martorana A. G. Klein