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Datasheet for the decision of 24 April 2017

Case Number: T 2400/11 - 3.4.02

Application Number: 04749622.9

Publication Number: 1616207

IPC: G01N21/35

Language of the proceedings: EN

Title of invention:
METHOD AND APPARATUS FOR THE MONITORING AND CONTROL OF COMBUSTION

Applicant:
Zolo Technologies, Inc.

Headword:

Relevant legal provisions:
EPC 1973 Art. 56

Keyword:
Inventive step - (yes)

Decisions cited:

Catchword:

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Case Number: T 2400/11 - 3.4.02

D E C I S I O N
of Technical Board of Appeal 3.4.02
of 24 April 2017

Appellant: (Applicant)	Zolo Technologies, Inc. 4946 North 63rd Street Boulder, CO 80301 (US)
Representative:	V.O. P.O. Box 87930 2508 DH Den Haag (NL)
Decision under appeal:	**Decision of the Examining Division of the European Patent Office posted on 28 March 2011 refusing European patent application No. 04749622.9 pursuant to Article 97(2) EPC.**

Composition of the Board:

Chairman	R. Bekkering
Members:	F. Maaswinkel
	T. Karamanli

Summary of Facts and Submissions

I. The applicant lodged an appeal against the decision of the examining division refusing European patent application No. 04749622.9, published as international application WO 2004/090496 A2. This patent application relates to a sensing apparatus for monitoring and control of coal combustion using laser spectroscopy.

II. In the decision under appeal it was held that the subject-matter of claim 1 according to both the main and the auxiliary request then on file did not involve an inventive step (Articles 52(1) and 56 EPC) having regard to the disclosure in document D1 and using known design options from the skilled person's background knowledge:

D1: Allen M G: "Diode laser absorption sensors for gas-dynamic and combustion flows", Meas. Sci. Technol., IOP, Bristol, GB, vol. 9 no. 4, April 1998, pages 545 - 562, ISSN: 0957-0233.

In addition the examining division raised several objections under Article 84 EPC because of unclear expressions in claim 1 according to both the main and the auxiliary request.

III. With the statement setting out the grounds of appeal of 8 August 2011 the appellant filed amended claims according to a main and first to third auxiliary requests. As a precautionary measure, the appellant requested oral proceedings.

With a further letter of 28 September 2011 further amended claims according to a main and first to third

auxiliary requests were filed, replacing all previous requests on file.

IV. In a communication pursuant to Rule 100(2) EPC the board raised objections under Article 84 EPC 1973 and made further observations with respect to the claims and the other application documents.

V. With a letter dated 24 January 2017 the appellant filed new sets of claims according to a main, first, second and third auxiliary requests. With a further letter of 12 April 2017 an amended description was filed, replacing the description then on file.

VI. The appellant requested that the decision under appeal be set aside and that a patent be granted on the basis of the following documents:

Main Request: Claims 1 to 17 according to the Main Request filed with the letter of 24 January 2017;
First Auxiliary Request: Claims 1 to 17 according to the First Auxiliary Request filed with the letter of 24 January 2017;
Second Auxiliary Request: Claims 1 to 17 according to the Second Auxiliary Request filed with the letter of 24 January 2017;
Third Auxiliary Request: Claims 1 to 17 according to the Third Auxiliary Request filed with the letter of 24 January 2017;

For all requests:

Description: pages 1 to 44 as filed with the letter of 12 April 2017;
Drawings: sheets 1/6 to 6/6 as published.

VII. Independent claim 1 according to the Main Request reads as follows:

"A sensing apparatus (10) comprising:

more than one diode laser (120) each having a select lasing frequency;

a multiplexer (124; 60) optically coupled to more than one but fewer than all of the diode lasers (120), the multiplexer (124) outputting a multiplexed laser light, the multiplexed laser light being optically coupled to a proximal end of a pitch side optical fiber (126; 66);

an input fiber (122n; 66) optically coupled to one diode laser that is not optically coupled to the multiplexer (124);

an optical coupler (130; 134) optically coupled to a distal end of the pitch side optical fiber (126) and a distal end of the input fiber (122n);

a transmission fiber (132) optically coupled to the optical coupler (130);

a pitch optic (128; 48) optically coupled to a distal end of the transmission fiber (132; 68), the pitch optic being operatively associated with a combustion chamber (22; 54) and oriented to project a multiplexed laser output through the combustion chamber;

wherein wavelengths of the multiplexed laser light range from 1240 nm to 5200 nm and wavelengths of the un-multiplexed laser light are less than 1240 nm;

wherein the input fiber (122n; 66) is a single mode fiber;

wherein the pitch side optical fiber (126) provides single mode transmission of the multiplexed laser light;

wherein the one diode laser light would become multimodal after transmission through the pitch side optical fiber (126); and

wherein the transmission optical fiber (132) is a very short transmission section of multimode fiber that does not allow the higher order spatial modes for the one diode laser light to develop;

the sensing apparatus further including:
a catch optic (52) operatively associated with the combustion chamber (22; 54) in optical communication with the pitch optic (128; 48) to receive the multiplexed laser output projected through the combustion chamber;

a catch side optical fiber (70) optically coupled to the catch optic at a proximal end;

a demultiplexer (62) optically coupled to a distal end of the catch side optical fiber, the demultiplexer demultiplexing laser light of each of the select lasing frequencies; and

a detector (58) optically coupled with the demultiplexer, the detector being sensitive to one of the select lasing frequencies."

Claims 2 to 17 are dependent claims.

VIII. The appellant's arguments may be summarised as follows:

The claims were based on the claims of the main request on which the decision of the examining division was based with amendments in order to overcome the objections under Article 84 EPC. Furthermore apparatus claim 1 now specified that the input (optic) fiber 1 was a single mode fiber. This feature was disclosed at page 36, starting at line 9 of the description as published in the context of the embodiments in Figures 2 and 8. Claim 1 had been formulated in the one-part

form and reference signs had been included, thereby meeting the issues raised in the communication of the board. Furthermore in the description prior-art document D1 had been acknowledged. Therefore the patent application met the requirements of the EPC.

With respect to the prior art, document D1 disclosed a laser absorption spectroscopy apparatus comprising a number of lasers each generating outputs with separate wavelengths. Each laser output was coupled into an individual fiber. By means of a fused Nx2 fiber-coupler all individual laser outputs of separate wavelengths were coupled into a multiplexed fiber signal channel, which multiplexed light was then projected through a chamber and detected for analysis (Figure 2). In the example illustrated in Figure 3 three lasers covering a wavelength range of about 500 nm were used.

The invention addressed the problem that, in order to retrieve more relevant data from the processes occurring in a combustion chamber, it was desired to apply an optical probe beam including wavelengths that were more widely separated, so that absorption spectroscopy could simultaneously be performed across several widely spaced absorption lines of interest, while maintaining measurement accuracy.

To this aim the invention provides a sensing apparatus that allowed selecting widely separated wavelengths in the optical probe beam while deterioration in measurement accuracy was counteracted by transmitting an individually selected wavelength of less than 1240 nm separate from wavelengths longer than 1240 nm which were multiplexed to a coupler via a separate fiber. By providing separate fibers, both the input fiber and the pitch side optical fiber could be optimized such that

they were single mode and had an optimal transmission characteristic for their respective partial beams, so that undesired losses and mode noise could be counteracted, while sensitive components might still be placed remotely from the hostile measurement zone.

The analysis in Section 5.1 of the decision under appeal appeared very confusing. In particular in Sections 5.1.3 and 5.1.4 the examining division considered apparently that a multiplexer as defined in claim 1 was synonymous to the Nx2 fiber coupler in the embodiment of Figure 2 of D1. This was not correct since a multiplexer was designed for very specific wavelengths and was typically at least 3dB more efficient than a coupler since the light from a coupler comes out of two fibers instead of one (viz. the Nx2 coupler in Figure 2 of D1, compared to the multiplexers 60 and 124 in Figures 2 and 8 of the present patent application).

The appellant also noted that in Section 5.1.2 of the decision it had been argued with reference to page 522, left column, lines 14 - 16, that in D1 a catch side optical fiber optically coupled to the catch optic at a proximal end would be used. However, when reading that second paragraph on page 552, left column, in its entirety it was concluded that D1 explicitly recommended the use of directly illuminating the signal photo detector at the catch side (viz. lines 31 - 32).

Therefore, the invention as claimed in claim 1 was novel and inventive with regard to document D1.

Reasons for the Decision

1. The appeal is admissible.

2. Amendments - Main Request

The board is satisfied that the passages in the description as published indicated by the appellant constitute a fair basis for the amendments in claim 1. In the new set of claims also the board's clarity objections have been overcome.

Therefore the claims comply with the corresponding provisions of Article 123(2) EPC and Article 84 EPC 1973.

3. Patentability - Main Request - Claim 1

In the decision under appeal the novelty of the subject-matter of claim 1 of the main request then on file had not been questioned. However, the subject-matter of claim 1 was considered not to involve an inventive step, therein exclusively referring to document D1 and the background knowledge of the skilled person.

3.1 The argumentation in Section 5.1 of the decision under appeal appears to be quite unusual, since it fails to specify in detail the differences between the claimed device and the sensor configuration shown in Figure 2 of D1 and, as a result, a proper problem/solution has not been carried out.

In the following the features of present claim 1 according to the Main Request and the configuration in

Figure 2 of D1 are compared (strike-through features are not disclosed in D1):

3.1.1 A sensing apparatus comprising: more than one diode laser each having a select lasing frequency (*D1: fiber pig-tailed lasers, see Figure 3 and p.552, rhc, 2nd para.: "Figure 3 is an example absorption scan from a three-wavelength version of the multiplexed configuration shown in figure 2..."*);

3.1.2 a multiplexer (*see 3.1.1 supra, "the multiplexed configuration shown in figure 2"*) optically coupled to more than one ~~but fewer than all~~ of the diode lasers, the multiplexer outputting a multiplexed laser light, the multiplexed laser light being optically coupled to a proximal end of a pitch side optical fiber (*see Figure 2, the "Multiplex Fiber Signal Channel" at the output of the fused Nx2 optical coupler*);

3.1.3 ~~an input fiber optically coupled to one diode laser that is not optically coupled to the multiplexer~~;

3.1.4 ~~an optical coupler optically coupled to a distal end of the pitch side optical fiber and a distal end of the input fiber~~;

3.1.5 ~~a transmission fiber optically coupled to the optical coupler~~ (*since D1 does not disclose a further "optical coupler" within the meaning of claim 1 the transmission fiber would be identical with the "Multiplexed Fiber Signal Channel", but this fiber has already been defined supra...*);

3.1.6 a pitch optic ~~optically coupled to a distal end of the transmission fiber~~, the pitch optic being operatively associated with a combustion chamber and oriented to

project a multiplexed laser output through the combustion chamber;

3.1.7 wherein wavelengths of the multiplexed laser light range from 1240 nm to 5200 nm (*see Figure 3*) ~~and wavelengths of the un-multiplexed laser light are less than 1240 nm~~;

3.1.8 ~~wherein the input fiber is a single mode fiber~~;

3.1.9 wherein the pitch side optical fiber provides single mode transmission of the multiplexed laser light (*p. 551, rhc, 2nd para.*);

3.1.10 ~~wherein the one diode laser light would become multimodal after transmission through the pitch side optical fiber~~; and

3.1.11 ~~wherein the transmission optical fiber is a very short transmission section of multimode fiber that does not allow the higher order spatial modes for the one diode laser light to develop~~;

3.1.12 the sensing apparatus further including:
a catch optic operatively associated with the combustion chamber in optical communication with the pitch optic to receive the multiplexed laser output projected through the combustion chamber (*a catch optic -"capture lens"- is one of the possibilities disclosed at p.552, lhc, 2nd para.*);

3.1.13 a catch side optical fiber optically coupled to the catch optic at a proximal end (*idem*);

3.1.14 a demultiplexer optically coupled to a distal end of the catch side optical fiber, the demultiplexer

demultiplexing laser light of each of the select lasing frequencies; and a detector optically coupled with the demultiplexer, the detector being sensitive to one of the select lasing frequencies (*in the specific embodiment of Figures 2 and 3, D1 discloses a time-domain multiplexed arrangement with a single detector; however, alternatively, also wavelength-domain multiplexing using a grating-demultiplexer is proposed, see p.552, rhc, 3rd para.*).

3.2 As can be appreciated by the strike-through features (*i.e. features not disclosed in the embodiment of Figure 2 of D1*), there are rather more features in claim 1 not disclosed in document D1 than enumerated in point 5.1.5 of the decision under appeal. This can be more easily visualised by looking at the embodiment in Figure 8 of the patent application:

- A multiplexer (124) being coupled to fewer than all of the laser diodes, feature 3.1.2;
- an un-multiplexed laser with wavelength 760nm, i.e. less than 1240nm (*feature 3.1.7 supra*);
- wherein the input fiber is a single mode fiber, feature 3.1.8;
- wherein the one diode laser light would become multimodal after transmission through the pitch side optical fiber (*here: fiber 126, SMF28*), feature 3.1.10;
- an input fiber coupled to the un-multiplexed diode laser as defined in feature 3.1.3 (*fiber SM750*);
- an optical coupler 130 as defined in feature 3.1.4;
- a transmission fiber 132 as defined in feature 3.1.5; and
- the particular properties of the transmission fiber defined in feature 3.1.11.

3.3 Furthermore, the formulation of the technical problem identified in point 5.1.6 of the decision under appeal as "*reducing the total length of optical fiber used in the apparatus, while maintaining the losses due to mode-noise as low as possible*" is not comprehensible, since this "problem" does not exist in the embodiment in Figure 2 of D1, the multiplexed fiber signal channel being a single-mode fiber, see p. 551, rhc, l.10; also p.552, lhc, l.19.

Therefore:

(a) in the embodiment of Figure 2 of D1 the total length of optical fiber cannot be reduced; and

(b) by using single-mode fibers the losses due to mode-noise (*i.e. occurring in a multi-mode fiber by development of higher-order modes and subsequent interference with the lowest order mode*) are already at the lowest possible level.

3.4 Comparing the Figure 2 configuration of document D1 and the embodiment as defined in claim 1 (*see Figures 2 and 8 of the patent application*) it appears that the major difference between these relates to the extension of the wavelength range of the diode lasers from 1392 - 1654 nm in Figure 3 to a value less than 1240nm (*in fact, 760 nm*). The skilled person consulting D1 may be motivated to extend this range in this way, since he learns, at p. 550, lhc, 1st para., that species such as molecular oxygen, NO_x and NO_2 can be detected in this wavelength range.

Document D1 does not provide an explicit teaching in which way the configuration in Figure 2 should be modified for shorter wavelengths: At p.551, rhc, 2nd para., the use of couplers between 760 nm and 1.55 µm is mentioned, but without any details. Section 5.1 of

this document discloses the application of diode lasers near 760 nm for spectroscopic measurements of O_2. As is illustrated in Figure 5 of document D1 (*see also the reference to Miller et al 1996 at p.553, rhc, 2nd para.*), a single Fabry-Perot AlGaAs laser and a 1x4 splitter delivers via fiber-coupled launch collimators two signal channels to an aeroengine inlet (*and to two reference channels, not shown in Figure 5*). Therefore, an obvious extension of the sensor configuration in Figure 2 of D1 to shorter wavelengths (*e.g. to 670 nm*) would involve to add the {670 nm laser / single mode fiber / launch collimator} combination as shown in Figure 5 of D1 to the configuration in Figure 2.

3.5 In that case, when considering the "Fused Nx2 Fiber-Coupler" in Figure 2 of D1 as the "multiplexer" in claim 1 (*as in point 3.1.2 supra*), the new arrangement would probably include an independent fiber-optic arrangement comprising the 670 nm laser, coupled to the single-mode (670 nm) fiber and a fiber-coupled collimator.

3.6 The skilled person would not contemplate combining the 670 nm laser as a further input to the Fused Nx2 Fiber-Coupler, because a combination of such widely different wavelengths in one single-mode fiber is not possible. Therefore the solution would be to keep the shorter wavelength-diagnostic as shown in Figure 5 of D1 completely separated from the multi-wavelength signals shown in Figure 2. Then the combined set-up would have a (single-mode) Multiplexed Fiber Signal Channel as in Figure 2 coupled with a lens assembly (*p.551, rhc, last para.*) and a further (*parallel*) single-mode fiber for the 670 nm signal coupled to a collimator as in Figure 5.

3.7 By integrating the additional 670 nm laser diode and optics shown in Figure 5 of D1 into the configuration in Figure 2, the resulting arrangement would include two fibers:

- a (single-mode) multiplexed fiber signal channel; and
- a further single-mode fiber for 670 nm wavelength,

wherein each fiber is coupled to its own "pitch optic", respectively to a "fiber-coupled launch collimator". In contrast, in the apparatus shown in Figure 8 of the patent application and defined in claim 1, the two fibers are combined in an optical coupler 130, pass through a "short length of transmission fiber" 132, and enter the combustion chamber via one pitch optic 128. This fiber 132 is "…a very short transmission section of multimode fiber that does not allow the higher order spatial modes for the one diode laser light to develop".

3.8 Therefore, in addressing the technical problem to extend the wavelength range of the configuration in Figure 2 of document D1 to shorter wavelengths, e.g. in order to detect molecular oxygen components (*see point 3.4 supra*), the skilled person would find a proper solution in the same document, ending up with a configuration with two independent single mode fibers (SMF) and two pitch optics at the entrance windows.

3.9 Neither document D1 nor the further documents cited in the examination proceedings disclose or suggest an additional coupler combining the two SMF and providing the particular transmission optical fiber.

4. Therefore, the subject-matter of claim 1 is novel (Article 54(1) EPC 1973) and involves an inventive step (Article 56 EPC 1973).

5. Claims 2 to 17 are dependent claims and therefore their subject-matter is equally inventive.

6. Since the appellant's Main Request is allowable there is no need to address the First to Third Auxiliary Requests. There was also no need to hold oral proceedings.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the department of first instance with the order to grant a patent with the following documents:

Claims: Nos. 1 to 17 according to the Main Request filed with the letter of 24 January 2017;
Description: Pages 1 to 44 as filed with the letter of 12 April 2017;
Drawings: Sheets 1/6 to 6/6 as published.

The Registrar: The Chairman:

C. Rodriguez Rodriguez R. Bekkering

Decision electronically authenticated