



- (51) **International Patent Classification:**
G01N 21/85 (2006.01) *G01N 33/28* (2006.01)
- (21) **International Application Number:**
PCT/EP2015/058487
- (22) **International Filing Date:**
20 April 2015 (20.04.2015)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
1409303.3 26 May 2014 (26.05.2014) GB
- (71) **Applicant:** AKTIEBOLAGET SKF [SE/SE]; S-41550 Göteborg (SE).
- (72) **Inventors:** STORKEN, Jozef Maria; Torenvalk 15, NL-3435 ZN Nieuwegein (NL). TATAR, Florin; Ghandilaan 74, NL-2622 GE Delft (NL).
- (74) **Agents:** TWEEDLIE, Diane et al.; SKF B.V., Kelvinbaan 16, NL-3439MT Nieuwegein (NL).
- (81) **Designated States** (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

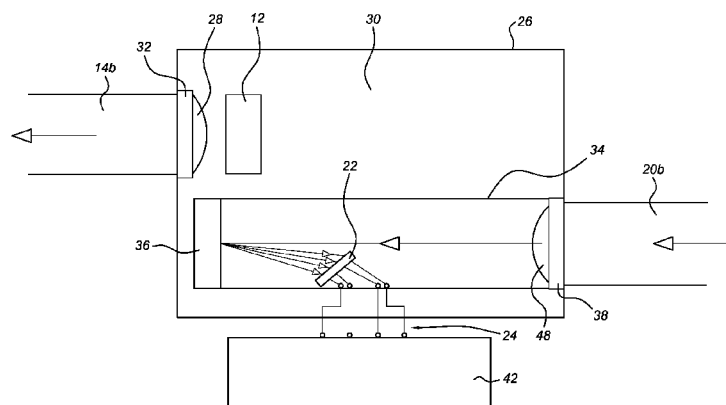
- (84) **Designated States** (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) **Title:** SENSOR FOR DETECTING WATER IN OIL

Fig. 2



(57) **Abstract:** A system for detecting the presence of water in oil, comprises a detection head (16) comprising a gap (18) in which oil to be monitored may be received; at least a first optical fibre (14) having a first end (14a), optically coupled to transmit light across the gap (18); a micro electro-opto-mechanical (MEOM) device (26), the MEOM device (26) comprising a photoemitter (12) and a photo-detector (22) integrated onto a silicon based substrate, the photoemitter (12) being optically coupled to transmit light into a second end (14b) of the first optical fibre (14) and the photo-detector (22) being arranged to receive transmitted light that has been transmitted across the gap; and an electronic interface (24) to the MEOM device for communicating therewith. A processor may be provided to analyse and compare the respective light signals to determine an amount of water present in the oil. By observing variations in absorption, the presence of water can be identified.



SENSOR FOR DETECTING WATER IN OIL

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to oil condition monitoring and in particular, to a
5 sensor for detecting the presence of water in oil or like substances. The invention relates particularly to a micro electro-opto-mechanical device for such detection and to a method of monitoring the presence of water in oil allowing low-cost implementation.

2. Description of the Related Art

[0002] Optical sensors have been used for oil condition monitoring for determining the
10 presence of debris or otherwise monitor deterioration of a lubricant. Such devices may operate by shining light through a small gap and analysing the transmitted light with a suitable optical sensor. Alternative sensors may make use of scattering of light and may operate over different frequencies including outside of the visible range. Oil condition monitoring may be significant in providing feedback in advance of likely failure of a
15 lubricant system. Action may be taken to perform maintenance or otherwise renew the lubricant.

[0003] Water in oil is of considerable concern to many mechanical systems. Minimal amounts of water may be absorbed by the oil during use, either from the atmosphere or by direct ingress of water into the system. As long as this water is in the absorbed state and the
20 oil is unsaturated, the concern is minimal. Nevertheless, as the concentration of water approaches the saturation level, emulsified and free water may occur, which can be highly detrimental, especially if exposure is prolonged. In bearings, the incompressibility of water relative to the oil can result in disruption of the oil film leading to excessive wear. Just one percent water in oil can reduce the life expectancy of a bearing by as much as 90 percent. For
25 ball or rolling element bearings, the localized pressure generated can cause spontaneous vaporization of the water, leading to erosive wear such as micropitting. The saturation level of water in oil may vary widely according to temperature and the type of oil and can range from 10 ppm to even 10000 ppm. Existing sensors capable of measuring the presence of water (free and dissolved) include capacitive sensors and Karl Fischer titration sensors. Both

-2-

of these methods require considerable time for the sensor to reach equilibrium and are not ideal for rapidly changing conditions. Spectral analysis using Fourier Transform Infrared Spectroscopy (FTIR) has been used but is a relatively complex and costly procedure requiring calibration of the sensor relative to the spectrum produced with fresh oil. Spectral
5 analysers are also relatively costly, bulky and sensitive devices for installation in many environments where mechanical systems are located.

[0004] It would thus be desirable to provide for a low-cost and simple sensor arrangement that could reliably identify the presence of water in oil in real time.

BRIEF SUMMARY OF THE INVENTION

10 [0005] According to the invention there is provided a system for detecting the presence of water in oil, comprising: a detection head comprising a gap in which oil to be monitored may be received; at least a first optical fibre having a first end, optically coupled to transmit light across the gap; a micro electro-opto-mechanical (MEOM) device, the MEOM device
15 comprising a photo-emitter and a photo-detector integrated onto a silicon based substrate, the photo-emitter being optically coupled to transmit light into a second end of the first optical fibre and the photo-detector being arranged to receive transmitted light that has been transmitted across the gap; and an electronic interface to the MEOM device for communicating therewith. In this context a MEOM device is intended to include any
20 miniature electro-opto-mechanical device that is integrated onto a single semiconductor chip. The proposed MEOM device can be inexpensively produced by mass production techniques, making the system relatively inexpensive. Such systems may be permanently integrated into mechanical systems for conditioning monitoring purposes.

[0006] Various implementations of the system may be foreseen. In particular, the detection head may be either transmissive or reflective. In the former case, a second optical fibre may
25 be provided, having a first end optically coupled to receive transmitted light, transmitted across the gap from the first end of the first optical fibre and having a second end optically coupled to transmit light to the photo-detector. In the alternative reflective implementation, the gap may comprise a reflective surface opposite to the first end of the first optical fibre and arranged to reflect transmitted light back into the first end of the first optical fibre. The
30 second end of the first optical fibre is then also optically coupled to the photo-detector. the

-3-

light source and the interferometer may be coupled via an optical switch. The photo-emitter and photo-detector may be coupled to the second end of the first optical fibre by an optical switch, which may be in the form of a semi-reflective mirror or prism. Other similar beam splitters may also be used. These transmissive and reflective arrangements have been further
5 described in related applications WO2014/090315 and PCT/EP2013/076791, the contents of which are hereby incorporated by reference in their entirety.

[0007] The photo-emitter may be any suitable light source. In one preferred form, it comprises a light emitting diode (LED), in particular a broadband LED. It may also be an incandescent light source. The photo-emitter is preferably operable to transmit light over a
10 broad spectrum in the IR region. The IR region in the range from 850 nm to 1750 nm is particularly favourable. Near infra red light shows good absorption properties for water while being only slightly affected by other contaminants in the oil.

[0008] The light may be detected over a broad spectrum. Most preferably however, the photo-detector comprises a spectrally selective detector operable to detect light over a narrow
15 band of 100 nm or less, preferably in the regions around 1250 nm and/or 1400 nm. The light is thus analysed in regions of the spectrum where water absorption peaks are present. For most oils, such absorption peaks may be identified at around 1250 nm and around 1400 nm and analysis in one or both of these specific regions is preferred.

[0009] The MEOM device preferably comprises appropriate micro-machined light guides
20 for guiding the transmitted light to the photo-detector. The light preferably enters the MEOM device through a window, such as a sapphire window, and may be further focussed by appropriate lenses towards the photo-detector. The construction of the MEOM device may be otherwise conventional. The MEOM device may further comprise a diffraction grating, arranged within the light guide to selectively direct chosen wavelengths of the transmitted
25 light onto the photo-detector. The diffraction grating is preferably micro-machined together with the MEOM device as an integrated solution, whereby the diffraction grating and photo-detector act as a miniature spectro-analyser. Devices of this type are available such as the NIR 1.7 Microspectrometer from InsionTM.

[0010] The system preferably further comprising a processor, operatively connectable to
30 the electronic interface for driving and interrogating the MEMS device. The processor may be a stand-alone device dedicated to the MEOM device or may be part of a larger system

-4-

such as a computer. Preferably, the processor is arranged to monitor a light signal representing light received at the photo-detector and to determine an amount of fluctuation of the light signal with time. The processor may further be arranged to compare the amount of fluctuation with a predetermined value representing a saturation level of the oil. The principle
5 by which this saturation level may be determined is extensively described in related application PCT/EP2012/075437. Accordingly, it has been observed that a significant change in signal characteristic of the transmitted light is to be observed at the point at which free water appears in the oil. Below the saturation level, the transmitted light signal as received by the photo-detector is relatively stable and only steadily decreases in intensity
10 with increasing absorbed water content. As the amount of water approaches saturation, the light signal becomes highly unstable and may appear noisy. Without wishing to be bound by theory, it is believed that bubbles of free water are formed within the oil in a manner similar to cavitation or boiling of a liquid. As these bubbles pass through the gap, they disturb the signal, effectively leading to greater absorption of the light and a lower light signal. A
15 significant advantage of the above effect is that the system can be easily calibrated in-situ to the saturation level, without requiring knowledge of either the oil or system characteristics. Additionally, the system can provide real-time results with negligible delay in identifying the presence of free water in the oil.

[0011] The system as described above may be implemented in any situation where
20 monitoring of oil condition is required. Most preferably, the detection head is located in an oil supply line of a mechanical system such as a gearbox, engine, bearing or the like.

[0012] The invention also relates to a method for detecting the presence of water in oil using a system as described above or hereinafter. The method may comprise passing light through the oil from the photo-emitter to the photo-detector; monitoring the light signal
25 received at the photo-detector; and analysing and comparing the light signal to determine an amount of water present in the oil. Analysis of the light signal to determine an amount of fluctuation of the signal may comprise monitoring the amount of fluctuation of the light signals to identify a step change representing saturation of the oil and generating a saturation signal indicative of saturation when the light signal indicates fluctuation of more than a
30 predetermined value.

-5-

[0013] In one embodiment, determining an amount of fluctuation may comprise measuring a peak to peak variation of the light signal within a sampling period. The sampling period may be chosen depending on various factors, including the sampling rate at which measurements of the light signal are taken and also based on physical factors such as the flow rate of the oil being monitored, the nature of the oil and other physical factors. In general, with the onset of free water the signal fluctuation may increase ten-fold or more and a predetermined value of 5 may be sufficient to provide reliable indication while avoiding false alarms. In other circumstances, a predetermined value of 2 may provide more sensitive response and predetermined values of below 2 may be applicable, in particular where signal smoothing has previously been applied. It will be understood that the sampling period will include at least two samples, preferably at least four samples and more preferably at least 10 samples. The sampling period may be between 1 second and 10 seconds, preferably between 2 seconds and 5 seconds. A sample rate of between 1 Hz and 10 Hz may be used, preferably around 2Hz, again depending on the flow rate. In general, for a higher flow rate of the oil through the gap, a higher sample rate may be required for the same sensitivity.

[0014] According to one method of analysis, saturation may be identified when a ratio of the light signal fluctuation in a second sampling period to the light signal fluctuation in a first sampling period exceeds a predetermined value. The predetermined value may be determined according to the nature of the oil and other physical factors. In general, with the onset of free water the signal fluctuation may increase ten-fold or more and a predetermined value of 5 may be sufficient to provide reliable indication while avoiding false alarms. In other circumstances, a predetermined value of 2 may provide more sensitive response and predetermined values of below 2 may be applicable, in particular where signal smoothing has previously been applied.

[0015] According to a further aspect of the invention, the method may further comprise determining the time that the oil remains above its saturation level. Once free water is detected in the oil, a timer may register the time elapsed until the danger of free water has receded. This point may be determined by evaluating a number of successive sampling periods and determining that water is absent once absence of saturation signal has been determined for all of these periods. Alternatively, once an absolute value of the light signal corresponding to the saturation level has been determined, the absence of free water may be

indicated once the absolute value of one or more of the light signals returns to a value distant from the saturation level.

[0016] According to an alternative method, the exposure of the system to free water may be determined by integrating the saturation signal with respect to time. Based on a flow rate of the oil through the sensor, integration of the signal may allow an approximate determination of the total amount of free water in the system. This may be used to provide further alarms and initiate appropriate actions in the event that a given exposure is exceeded.

[0017] A significant advantage of the present invention is that the sensors need not be pre-calibrated and may be calibrated in-situ based on recognition of the saturation level. In the event that greater accuracy is required in the region of absorbed water, the method may comprise calibrating the sensors for a sample of oil having a water content below the saturation level and subsequently determining a linear relation between the light signal and the water content when saturation of the oil is detected. Such a simple calibration may be achieved in a laboratory by calibrating the sensors against a Karl Fischer titration result. Alternatively, the sensors may be calibrated in the field by taking an oil sample for off-line analysis. Once calibrated, the sensors may be accurately used to also identify emulsified water in oil before the advent of free water.

[0018] The processor may be any appropriate processing device such as a computer or dedicated microprocessor. In addition to other control tasks, the processor is preferably arranged to determine when the fluctuation of the light signal exceeds the preset value. In particular the processor may carry out signal analysis, sampling and filtering as described above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The features and advantages of the invention will be appreciated upon reference to the following drawings of a number of exemplary embodiments, in which:

[0020] Figure 1 shows a schematic view of a system according to the invention for determining the absorption spectrum of an oil sample;

[0021] Figure 2 shows a schematic view of part of the system of Figure 1 in greater detail;

-7-

[0022] Figure 3 shows light intensity measurements for increasing water content measured in the system of Figure 1 for the wavelength of 1108 nm;

[0023] Figure 4 shows a schematic view of an alternative system according to the present invention.

5 DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0024] Figure 1 shows a schematic view of a system 10 for determining the absorption spectrum of an oil sample. The system comprises a photo-emitter 12, a first optical fibre 14, a detector head 16 comprising a gap 18, a second optical fibre 20, a photo-detector 22 and an electronic interface 24. The photo-emitter 12, the photo-detector 22 and the electronic interface 24 are integrated together onto a Micro Electro-Opto-Mechanical (MEOM) device 26. The first optical fibre 14 has a first end 14a coupled to the detector head 16 and directed to transmit light across the gap 18 towards a first end 20a of the second optical fibre 20. A second end 14b of the first optical fibre 14 is coupled to the MEOM device 26 and optically coupled to receive light from the photo-emitter. A second end 20b of the second optical fibre 20 is also coupled to the MEOM device 26 and optically coupled to transmit light to the photo-detector 22.

[0025] Figure 2 is a detailed view of the MEOM device 26 of Figure 1. The MEOM device 26 comprises a silicon substrate 30 onto which the various components have been fabricated using appropriate micro-electronic fabrication procedures. The photo-emitter 12 is fabricated on a region of the substrate 30 adjacent to the second end 14b of the first fibre 14 and is coupled into it by a first silicon lens 28 and first sapphire window 32. A light guide 34 is formed across the substrate 30 from the second end 20b of the second fibre 20 to a diffraction grating 36 located at an opposite side of the substrate 30. The second end 20b of the second fibre 20 is coupled into the light guide 34 through a second sapphire window 38 and second silicon lens 40. To one side of the light guide 34 is located the photo-detector 22, interconnected to the electronic interface 24. Also shown is a processor 42 that is connected to receive signals from the MEOM device 26 via the electronic interface 24. It will be understood that the processor 42 may be a dedicated processor or a remote processor e.g. forming part of a computer and that the signals from the MEOM device may be transmitted by any appropriate manner.

-8-

[0026] Figure 3 shows a representative trace of the signal that may be expected using the system of Figures 1 and 2. Based on testing in a test setup the transmitted light received through a gap of 0.5 mm for an oil sample is shown as recorded over a number of hours, during which the concentration of water in the oil was steadily increased until the saturation level was reached (100% saturated). After this the water concentration was further increased to about 0.4% water. The light intensity measurements for the test are shown in Figure 3 for the wavelength of 1108 nm. The result shows a strong and stable response to the ever increasing levels of water content. As the sample reaches saturation, the sensor records significant fluctuation in the signal. The sampling rate was 2 Hz. The skilled person will recognize that digital filtering such as a moving point average could be used to further smooth the signal.

[0027] Figure 4 shows a schematic view of a system 100 according to a second embodiment of the invention. In this embodiment, a single optical fibre 114 is used, coupled at its first end 114a to a detector head 116, having a gap 118. In this case, a surface of the detector head 116, facing the first end 114a of the optical fibre 114 is formed as a mirror 117, whereby light emitted from the optical fibre 114 is reflected back into the first end 114a thereof. The first end 114a of the optical fibre is also provided with a semi-reflective surface 115. The second end 114b of the optical fibre 114 is coupled to a MEOM device 126 comprising a photo-emitter 112, a photo-detector 122, an electronic interface 124 and a diffraction grating 136, integrated onto a substrate 130. Additionally, there is provided a semi-reflective mirror 137, which acts as an optical switch between the photo-emitter 112 and the diffraction grating 136 as described further in detail below.

[0028] In use, the detector head 116 is located within a mechanical system (not shown) such that oil A is received in the gap 118. Light from the photo-emitter 112 is coupled into the optical fibre 114 and guided through the optical fibre 114 to exit from the first end 114a. A portion of the light is reflected internally by the semi-reflective surface of the end face 115 and returns through the optical fibre as first light signal S1. The remainder of the light passes into and through the oil A in the gap 118 and impinges on the mirror 117, which reflects it back across the gap 118 and into the first end 114a of the optical fibre 114 as second light signal S2.

[0029] The first and second light signals S1, S2 are transmitted through the optical fibre 114 and the semi-reflective mirror 137 to the diffraction grating 136. The diffraction grating 136 is selectively deflects the different wavelengths onto the photo-detector 122 which can thus determine the frequency at which the signals S1, S2 constructively interfere. In general, once determined, this frequency will remain relatively stable for a given configuration and can be identified as a maximum in the combined signal $S1 + S2$.

[0030] The first light signal S1 may be used as a reference signal. The second light signal S2 is added to the first light signal S1 to ensure interference. Any amplitude changes caused by the fibre 114 bending will influence both signals S1 and S2 in a fixed proportional way. In this way amplitude changes caused by the fibre 114 bending becomes a known factor. The actual amplitude change that represents an oil in water saturation level can be calculated by removing the known factor. The measurement system is therefore not restricted to any fixed geometry and is more robust in use.

[0031] Thus, the invention has been described by reference to the embodiment discussed above. It will be recognized that this embodiment is susceptible to various modifications and alternative forms well known to those of skill in the art without departing from the spirit and scope of the invention. In particular, it will be understood that many different algorithms and signal analysis procedures may be carried out to determine the oil condition based on the sensor outputs. Accordingly, although specific embodiments have been described, these are examples only and are not limiting upon the scope of the invention.

CLAIMS

1. A system for detecting the presence of water in oil, comprising:

a detection head comprising a gap in which oil to be monitored may be received;

5 at least a first optical fibre having a first end, optically coupled to transmit light across the gap;

a micro electro-opto-mechanical (MEOM) device, the MEOM device comprising a photo-emitter and a photo-detector integrated onto a silicon based substrate, the photo-emitter being optically coupled to transmit light into a second end of the first optical fibre and the photo-detector being arranged to receive transmitted light that has
10 been transmitted across the gap; and

an electronic interface to the MEOM device for communicating therewith.

2. The system of claim 1, further comprising a second optical fibre, having a first end optically coupled to receive transmitted light, transmitted across the gap from the first end of the first optical fibre and having a second end optically coupled to transmit
15 light to the photo-detector.

3. The system of claim 1, wherein the gap comprises a reflective surface opposite to the first end of the first optical fibre and arranged to reflect transmitted light back into the first end of the first optical fibre and the second end of the first optical fibre is also
20 optically coupled to the photo-detector.

4. The system according to any preceding claim, wherein the photo-emitter comprises a light emitting diode.

5. The system according to any preceding claim, wherein the photo-emitter is operable to transmit light over a broad spectrum in the IR region.

25 6. The system according to any preceding claim, wherein the photo-detector comprises a spectrally selective detector operable to detect light over a narrow band of 100 nm or less, preferably in the regions around 1250 nm and/or 1400nm.

-11-

7. The system according to any preceding claim, wherein the MEOM device further comprises a micro-machined light guide extending from a window, where the transmitted light enters the MEOM device, to the photo-detector.

5 8. The system according to claim 7, wherein the MEOM device further comprises a diffraction grating, arranged within the light guide to selectively direct chosen wavelengths of the transmitted light onto the photo-detector.

9. The system according to any preceding claim, further comprising a processor, operatively connectable to the electronic interface for driving and interrogating the MEMS device.

10 10. The system according to claim 9, wherein the processor is arranged to monitor a light signal representing light received at the photo-detector and to determine an amount of fluctuation of the light signal with time.

11. The system according to claim 10, wherein the processor is arranged to compare the amount of fluctuation with a predetermined value representing a saturation level of the oil.

15 12. The system according to any preceding claim, wherein the detection head is located in an oil supply line of a mechanical system.

13. A method for detecting the presence of water in oil using the system according to any preceding claim, comprising passing light through the oil from the photo-emitter to the photodetector; monitoring the light signal received at the photo-detector; and analysing and comparing the light signal to determine an amount of water present in the oil.

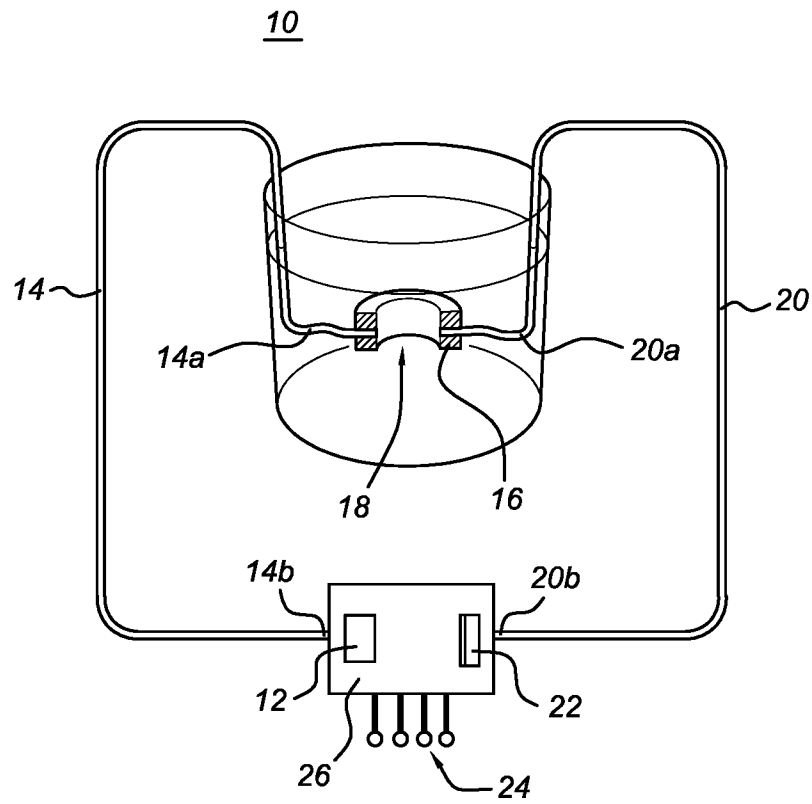
20 14. The method of claim 13, further comprising analysing the light signal to determine an amount of fluctuation of the signal; monitoring the amount of fluctuation of the light signals to identify a step change representing saturation of the oil and generating a saturation signal indicative of saturation when the light signal indicates fluctuation of more than a preset value.

25 15. The method of claim 14, wherein determining an amount of fluctuation comprises measuring a peak to peak variation of the light signal within a sampling period.

30

1/4

Fig. 1



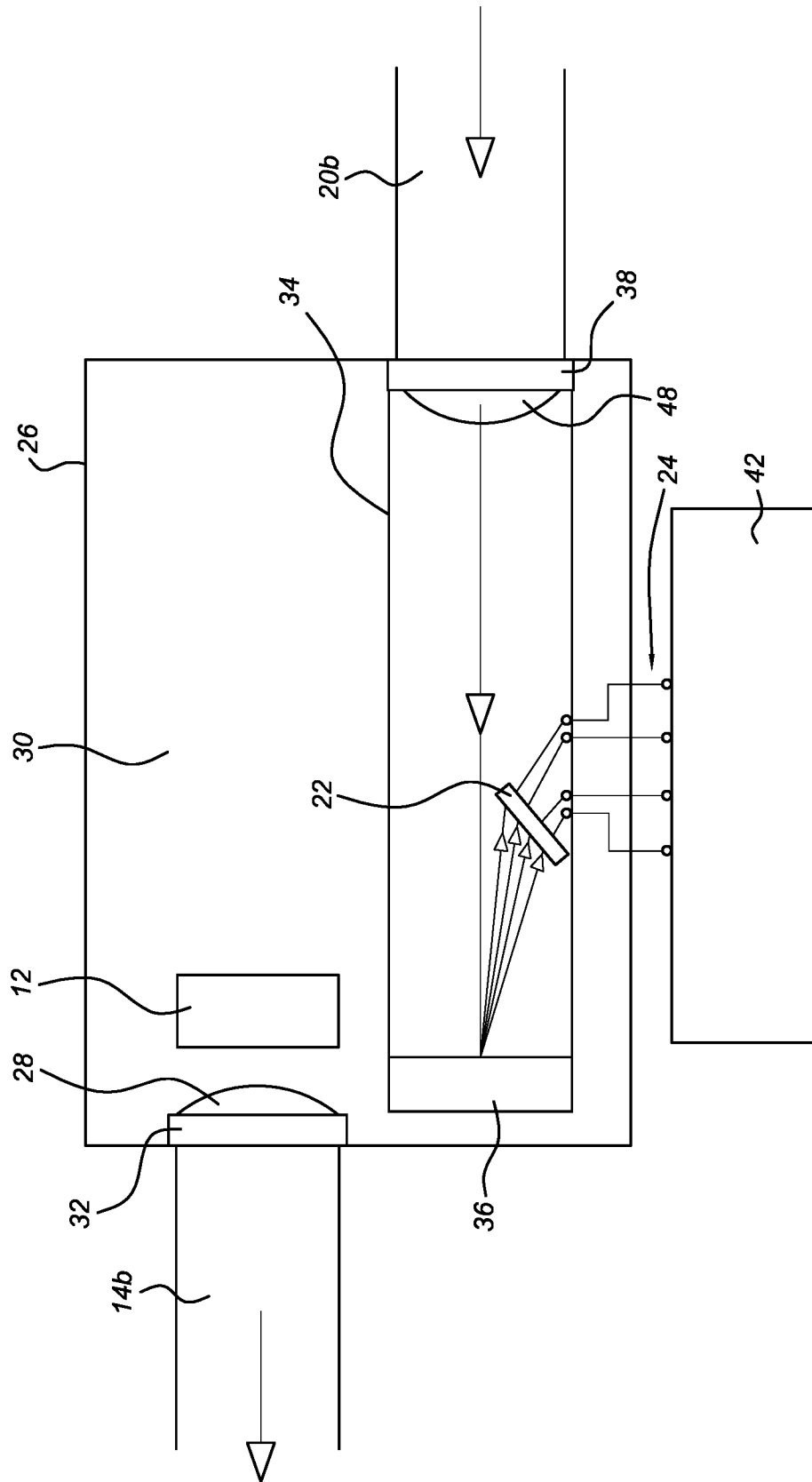


Fig. 2

Fig. 3

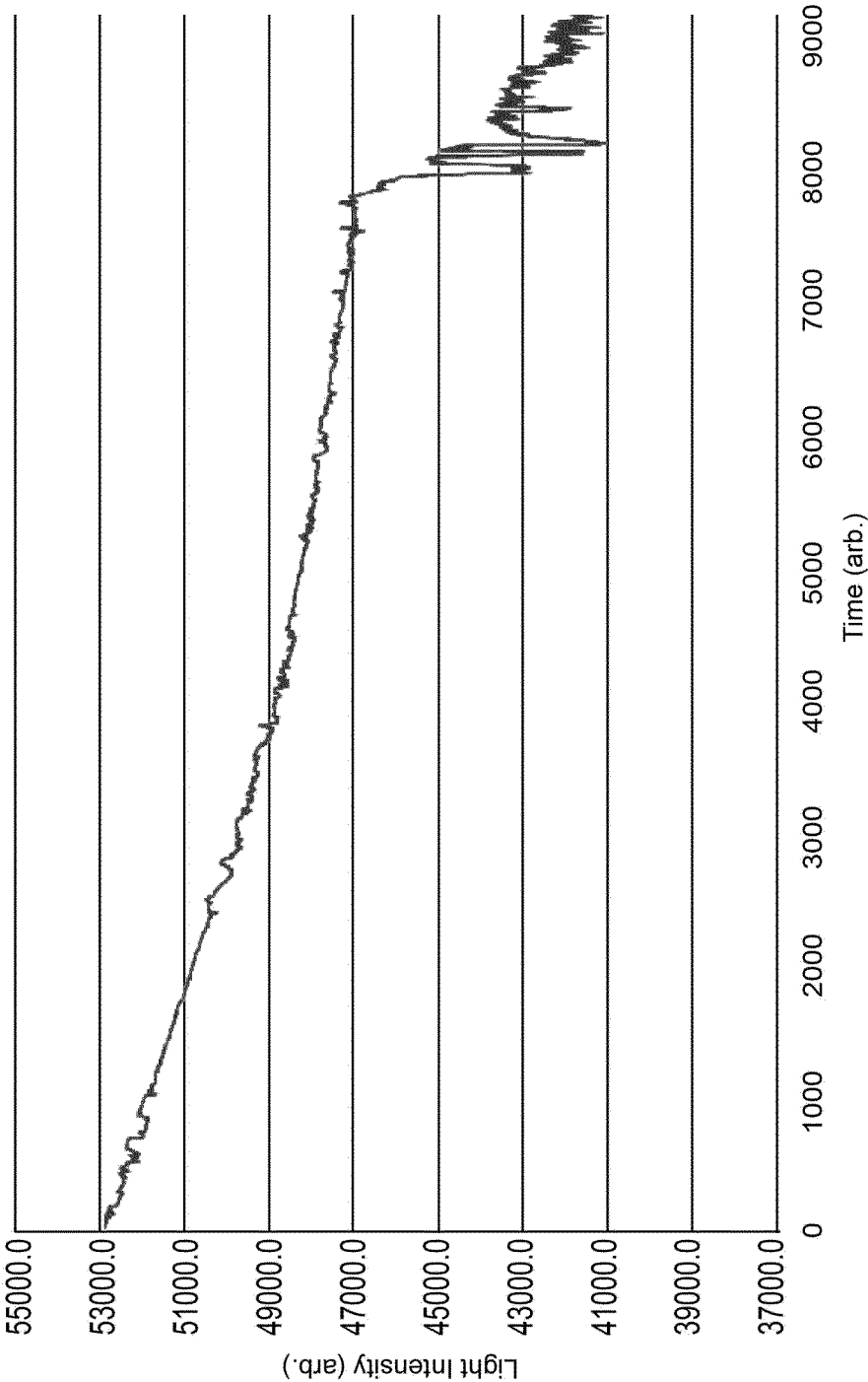
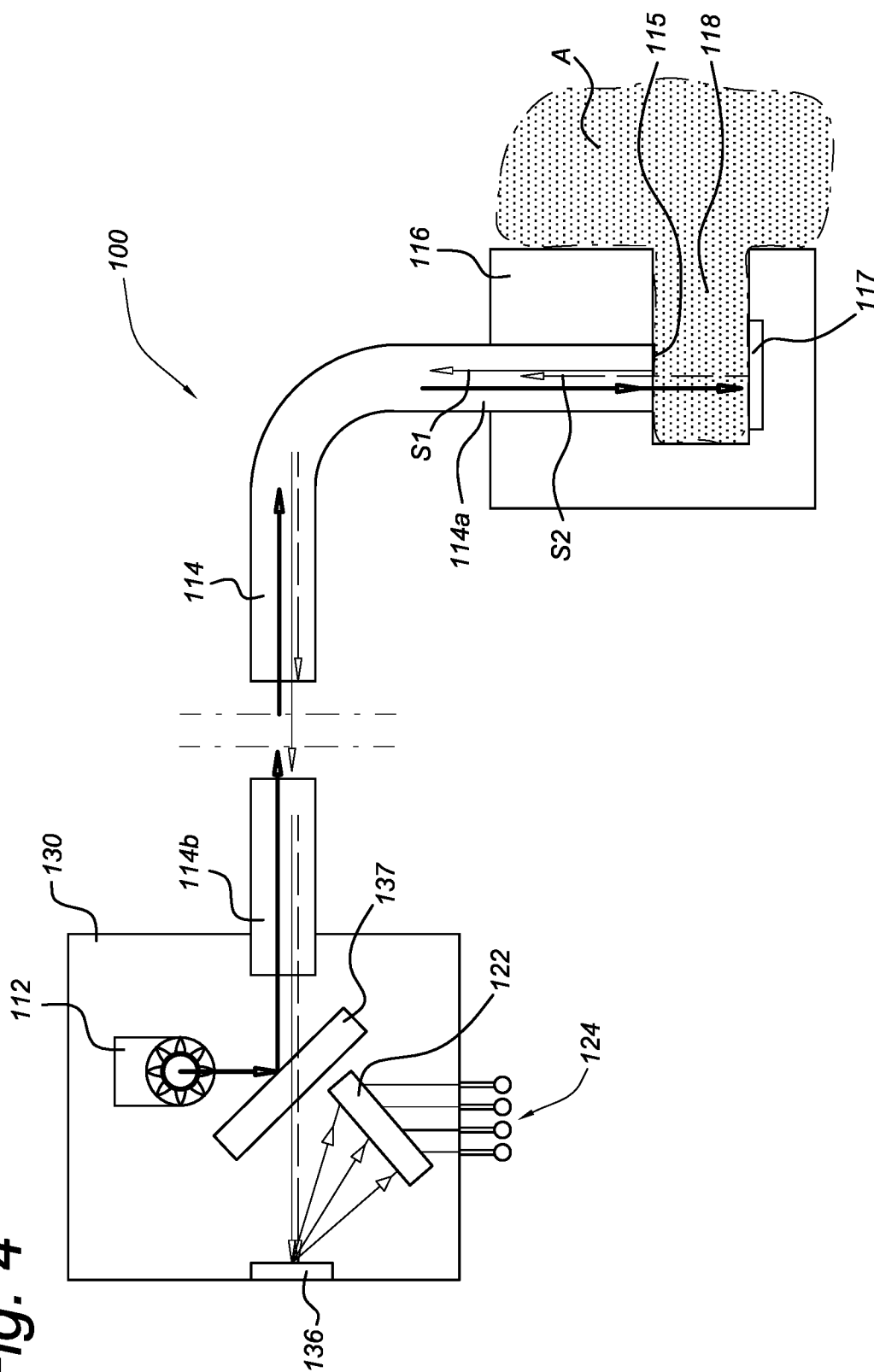


Fig. 4



INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2015/058487

A. CLASSIFICATION OF SUBJECT MATTER

INV. G01N21/85 G01N33/28
ADD.

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)

G01N

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7 339 657 B2 (COATES JOHN [US] ET AL) 4 March 2008 (2008-03-04)	1,2, 4-10,12, 13,15 3,11,14
Y	abstract; figures 5-9 column 1, lines 16-20 column 3, line 57 - column 4, line 12 column 10, line 17 - column 13, line 15 column 16, lines 58,59	
Y	----- US 2009/310138 A1 (VANHANEN JARMO [FI] ET AL) 17 December 2009 (2009-12-17) abstract; figure 1 paragraphs [0006], [0011] - [0013], [0039], [0045], [0047] ----- -/-	3



Further documents are listed in the continuation of Box C.



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 application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

29 July 2015

Date of mailing of the international search report

06/08/2015

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Brison, Olivier

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/058487

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2009/216464 A1 (KONG HO SUNG [KR] ET AL) 27 August 2009 (2009-08-27) abstract; figure 2 paragraphs [0002], [0023], [0034], [0040], [0042] - [0045] -----	11,14
A	US 2012/112072 A1 (JONES ROBERT [GB] ET AL) 10 May 2012 (2012-05-10) abstract; figure 1 paragraphs [0001], [0002], [0059] - [0064] -----	1-15
A	US 2011/249257 A1 (WILDSCHUETZ MARCUS [DE] ET AL) 13 October 2011 (2011-10-13) abstract; figures 2-4 paragraphs [0022], [0023] -----	1-15
A	US 7 768 646 B1 (MENTZER MARK A [US] ET AL) 3 August 2010 (2010-08-03) column 1, lines 13-23; figure 1 -----	1-15
A	WO 2007/042501 A1 (SOLVIAS AG [CH]; BUDNIK RALF [CH]; DANIGEL HARALD [CH]) 19 April 2007 (2007-04-19) abstract; figure 2 -----	1-15
A	US 2013/016336 A1 (XIE CHENG-GANG [GB]) 17 January 2013 (2013-01-17) abstract; figures 1-4 paragraphs [0001], [0003], [0010], [0031], [0037], [0039], [0042] -----	1,6,13

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2015/058487

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 7339657	B2	04-03-2008	AU 2002360271 A1 22-04-2003
		CA 2463151 A1 17-04-2003	
		EP 1444502 A2 11-08-2004	
		US 2004201835 A1 14-10-2004	
		WO 03030621 A2 17-04-2003	
US 2009310138	A1	17-12-2009	CN 101517398 A 26-08-2009
			CN 101517399 A 26-08-2009
			EP 2069764 A1 17-06-2009
			EP 2069765 A1 17-06-2009
			US 2009310138 A1 17-12-2009
			US 2010045989 A1 25-02-2010
			WO 2008034945 A1 27-03-2008
			WO 2008034946 A1 27-03-2008
US 2009216464	A1	27-08-2009	KR 20090090616 A 26-08-2009
			US 2009216464 A1 27-08-2009
US 2012112072	A1	10-05-2012	AU 2010255551 A1 12-01-2012
			CA 2764198 A1 09-12-2010
			CA 2894104 A1 09-12-2010
			EP 2438425 A2 11-04-2012
			US 2012112072 A1 10-05-2012
			WO 2010139965 A2 09-12-2010
US 2011249257	A1	13-10-2011	DE 102008056559 A1 27-05-2010
			EP 2356432 A1 17-08-2011
			US 2011249257 A1 13-10-2011
			WO 2010051806 A1 14-05-2010
US 7768646	B1	03-08-2010	NONE
WO 2007042501	A1	19-04-2007	EP 1991859 A1 19-11-2008
			WO 2007042501 A1 19-04-2007
US 2013016336	A1	17-01-2013	US 2013009048 A1 10-01-2013
			US 2013016336 A1 17-01-2013
			US 2015136963 A1 21-05-2015
			WO 2011073789 A2 23-06-2011
			WO 2011073790 A2 23-06-2011