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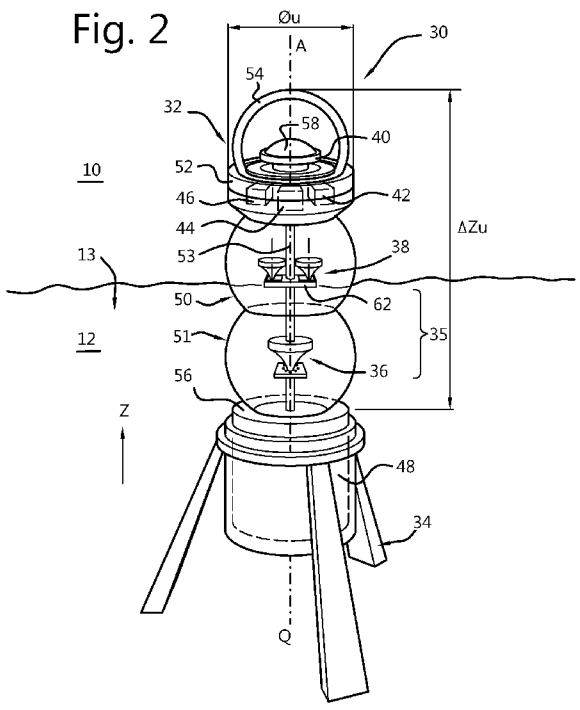
Published:
— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(54) Title: UNDERWATER WIRELESS OPTICAL COMMUNICATION UNIT AND SYSTEM

Fig. 2



(57) Abstract: An underwater wireless optical communication, UWOC, unit (30) for underwater deployment on a submerged earth layer (12) or structure (14, 16). The UWOC unit is configured for wireless optical communication in an underwater environment, and comprises an optical transmitter (36), an anidolic optical receiver (38), and a processor (44). The optical transmitter is configured to transmit data by emitting an optical signal (80) into the surroundings. The optical receiver includes an optical detector (62), which is omnidirectionally sensitive and configured to receive further optical signals approaching substantially along an azimuthal plane orthogonal to a nominal axis (A) through the UWOC unit. The processor is coupled to the optical receiver, and configured to process received further optical signals. The unit may be configured to determine an inter-unit distance between this unit and a second unit, by sending an optical interrogation signal to the second unit, and receiving an optical response signal from the second unit.

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[Continued on next page]

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INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2018/050467

A. CLASSIFICATION OF SUBJECT MATTER
INV. H04B10/112 H04B13/02
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)
H04B

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, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2008/027072 A2 (WOODS HOLE OCEANOGRAPHIC INST [US]; FARR NORMAN E [US]; FREITAG LEE [U) 6 March 2008 (2008-03-06)	1,2,5,6, 9,12
Y	figures 1, 3, 4, 5, 6A, 6B, 9, 10 page 7, lines 8-33 page 8 - page 9 page 10, lines 1-19 page 12 - page 29 page 30, lines 1-8 page 31, lines 7-33 page 34, lines 1-9	3,4,7,8, 13-17

Y	US 2006/008275 A1 (LACOVARA PHILIP [US] ET AL) 12 January 2006 (2006-01-12) figure 5 paragraph [0016]	7,8

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[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 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	Date of mailing of the international search report
28 February 2019	13/03/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Lobato Polo, I

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2016/088157 A1 (LAMPSERVE INC [JP]) 9 June 2016 (2016-06-09) the whole document	5
A	GUTIERREZ R M ET AL: "The silicon photomultiplier as a metasystem with designed electronics as metadevice for a new receiver-emitter in visible light communications", VISUAL COMMUNICATIONS AND IMAGE PROCESSING; 20-1-2004 - 20-1-2004; SAN JOSE,, vol. 9544, 1 September 2015 (2015-09-01), pages 95441P-95441P, XP060058861, DOI: 10.1117/12.2190161 ISBN: 978-1-62841-730-2 the whole document	5
Y	KHAN MAHMUDUR ET AL: "GPS-Free Maintenance of A Free-Space-Optical Link Between Two Autonomous Mobiles", IEEE TRANSACTIONS ON MOBILE COMPUTING, IEEE SERVICE CENTER, LOS ALAMITOS, CA, US, vol. 16, no. 6, 1 June 2017 (2017-06-01), pages 1644-1657, XP011648712, ISSN: 1536-1233, DOI: 10.1109/TMC.2016.2602834 [retrieved on 2017-05-04] figures 1, 3 Section 4.2	3,4, 13-17
Y	SCOPIGNO RICCARDO ET AL: "The potential benefits of on-board Li-Fi for the cooperation among vehicles", 2015 17TH INTERNATIONAL CONFERENCE ON TRANSPARENT OPTICAL NETWORKS (ICTON), IEEE, 5 July 2015 (2015-07-05), pages 1-6, XP033191708, DOI: 10.1109/ICTON.2015.7193411 [retrieved on 2015-08-12] figure 3 Section 4.1	3,4, 13-17
Y	US 2016/156420 A1 (DRUML NORBERT [AT] ET AL) 2 June 2016 (2016-06-02) figures 1, 3A paragraphs [0047] - [0049], [0076], [0077]	3,4, 13-17

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DANWEI WANG ET AL: "Time of flight based two way ranging for real time locating systems", ROBOTICS AUTOMATION AND MECHATRONICS (RAM), 2010 IEEE CONFERENCE ON, 1 June 2010 (2010-06-01), pages 199-205, XP055562043, Piscataway, NJ, USA DOI: 10.1109/RAMECH.2010.5513188 ISBN: 978-1-4244-6503-3 the whole document -----	3,4, 13-17
A	ZAFER SAHINOGLU ET AL: "Ranging in the IEEE 802.15.4a Standard", 2006 IEEE ANNUAL WIRELESS AND MICROWAVE TECHNOLOGY CONFERENCE, 1 December 2006 (2006-12-01), pages 1-5, XP055562049, DOI: 10.1109/WAMICON.2006.351897 ISBN: 978-1-4244-0849-8 the whole document -----	3,4, 13-17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NL2018/050467

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

1-9, 12-17

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1, 2, 5-9, 12

   An underwater wireless communication unit (UWOC) configured for wireless optical communication in an underwater environment, and comprises an optical transmitter, an anidolic optical receiver, and a processor.

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2. claims: 3, 4, 13-17

   A method for determining an inter-unit distance between a first and a second position based on the transmission of an interrogation signal by a first optical transmitter of a first UWOC unit, the reception of the optical interrogation signal with a second optical receiver of a second UWCO unit and a response of the second unit to the interrogation signal.

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3. claims: 10, 11

   A front end circuit for a silicon photomultipler (SiPM) used in the UWCO optical detector.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2018/050467

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2008027072 A2	06-03-2008	US 2007183782 A1	09-08-2007
		US 2011229141 A1	22-09-2011
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		DE 102015120850 A1	02-06-2016
		US 2016156420 A1	02-06-2016