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Inventor(s)	Nishimura; Naoki et al.

Optical communication device

Abstract

This optical communication device (1) is provided with a plurality of light-receiving elements (11) and a plurality of optical fibers (12). The plurality of optical fibers each includes a light-incident end portion (12a) for communication light and a light-emission end portion (12b) for communication light. The plurality of light-emission end portions is each arranged near each of the plurality of light-receiving elements. The plurality of light-incident end portions is each configured to be capable of being arranged in a predetermined position in a predetermined direction.

Inventors:	Nishimura; Naoki (Kyoto, JP), Sawa; Takao (Yokosuka, JP)
Applicant:	SHIMADZU CORPORATION (Kyoto, JP); JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND TECHNOLOGY (Yokosuka, JP)
Family ID:	1000008763752
Assignee:	SHIMADZU CORPORATION (Kyoto, JP); JAPAN AGENCY FOR MARINE-EARTH SCIENCE AND TECHNOLOGY (Yokosuka, JP)
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Primary Examiner: Bello; Agustin

Attorney, Agent or Firm: Muir Patent Law, PLLC

Background/Summary

TECHNICAL FIELD

(1) The present invention relates to an optical communication device.

BACKGROUND OF THE INVENTION

(2) Conventionally, an optical communication device for performing communication using communication light is known. Such an optical communication device is disclosed, for example, in Japanese Unexamined Patent Application Publication No. 2018-7069.

(3) The above-described Japanese Unexamined Patent Application Publication No. 2018-7069 discloses a first optical communication instrument (optical communication device) mounted on a submersible navigating underwater and a second optical communication instrument (optical communication device) mounted on a marine vessel or another submersible navigating underwater. Further, the above-described Japanese Unexamined Patent Application Publication No. 2018-7069 discloses that an optical signal using communication light which is visible light is transmitted through the water between the first optical communication instrument and the second optical communication instrument. Each of the first optical communication instrument and the second optical communication instrument is provided with one or a plurality of light-receiving elements inside a housing.

PRIOR ART DOCUMENT

SUMMARY OF THE INVENTION

Problems to be Solved by the Invention

(5) However, as described in the above-described Japanese Unexamined Patent Application Publication No. 2018-7069, in a conventional optical communication device, it is considered that each installation location of the plurality of light-receiving elements cannot be arbitrarily selected. Therefore, it is considered to be difficult to freely adjust each directivity of light received (light-receiving direction, light-receiving range, etc.) by the plurality of light-receiving elements. Therefore, it is considered that there is a disadvantage in that it is difficult to arbitrarily set the directivity of light received by the plurality of light-receiving elements as a whole. Further, as a method of arbitrarily realizing the directivity of light received by the plurality of light-receiving elements, for example, it is considered to adopt a classic method in which a black paper is placed in front of the light-receiving elements or a method in which a digital mirror device is used. However, these methods shield a part of the light reaching the light-receiving elements, and therefore, it is considered to be disadvantageous in that the methods basically worsen the performance (sensitivity) of the light-receiving elements. Therefore, it is considered that there is a problem that it is difficult to arbitrarily set the directivity of the light received by the plurality of light-receiving elements while maintaining all of the sensitivities of the plurality of light-receiving elements.

(6) The present invention has been made to solve the above-described problems. One object of the present invention is to provide an optical communication device capable of arbitrarily setting the directivities of light received by a plurality of light-receiving elements while maintaining all of the sensitivities of the plurality of light-receiving elements.

Means for Solving the Problem

(7) In order to attain the above-described object, the optical communication device according to one aspect of the present invention includes: a plurality of light-receiving elements configured to receive communication light, the plurality of light-receiving elements being provided so as to correspond to a plurality of channels; and a plurality of optical fibers configured to guide the communication light to the plurality of light-receiving elements, the plurality of optical fibers being provided so as to correspond to the plurality of light-receiving elements, wherein the plurality of optical fibers each includes a light-incident end portion for the communication light and a light-emission end portion for the communication light, wherein the plurality of light-emission end portions is each arranged near each of the plurality of light-receiving elements, and wherein the plurality of the light-incident end portions is each configured to be capable of being arranged at a predetermined position in a predetermined direction.

(8) Note that in the specification of this application, the terminology “near each of the plurality of light-receiving elements” denotes a broad concept including both the position itself of each of the plurality of light-receiving elements and the vicinity of the position of each of the plurality of light-receiving elements.

Effects of the Invention

(9) According to the present invention, as described above, a plurality of optical fibers for guiding communication light to a plurality of light-receiving elements is provided. The plurality of optical fibers is each configured to include a light-incident end portion for communication light and a light-emission end portion for communication light. The plurality of light-emission end portions is each arranged near each of the plurality of light-receiving elements. The plurality of light-incident end portions is each configured to be capable of being arranged at a predetermined position in a predetermined direction. With this, by using the optical fibers, it is possible to arbitrarily select the installation location where each of the plurality of light-receiving elements is installed. Further, by adjusting the positions and directions of the plurality of light-incident end portions, it is possible to freely adjust the directivity of light received (the light-receiving direction, the light-receiving range,

etc.) by each of the plurality of light-receiving elements. Therefore, it is possible to arbitrarily set the directivity of light received by the plurality of light-receiving elements as a whole. Also, unlike the case of adopting a method in which a black paper is arranged in front of the light-receiving elements or a method in which a digital mirror device is used as a method for realizing the arbitral light-receiving directivity, a part of the light incident on the light-receiving elements will not be shielded, and therefore, the sensitivity of the light-receiving element do not deteriorate. Consequently, it is possible to arbitrarily set the directivity of light received by a plurality of light-receiving elements while maintaining all of the sensitivities of the plurality of light-receiving elements.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

- (1) FIG. 1 is a schematic diagram showing a schematic configuration of an underwater optical communication system according to a first embodiment.
- (2) FIG. 2 is a schematic diagram showing a configuration of a light-receiving unit of an optical communication device according to a first embodiment.
- (3) FIG. 3A is a schematic diagram showing a first example of holding light-incident end portions of optical fibers by a light-incident end portion holder of an optical communication device according to a first embodiment. FIG. 3A is a schematic diagram showing a second example of holding light-incident end portions of an optical fiber by a light-incident end portion holder of an optical communication device by a first embodiment.
- (4) FIG. 4 is a schematic diagram showing an arrangement example of optical fibers of an optical communication device according to a first embodiment.
- (5) FIG. 5 is a schematic perspective view showing a lens and a lens holder of an optical communication device according to a second embodiment.

EMBODIMENTS FOR CARRYING OUT THE INVENTION

- (6) Hereinafter, some embodiments in which the present invention is embodied will be described with reference to the attached drawings.

First Embodiment

- (7) (Underwater Optical Communication System)
- (8) With reference to FIG. 1, a configuration of an underwater optical communication system **100** provided with an optical communication device according to a first embodiment will be described.
- (9) As shown in FIG. 1, the underwater optical communication system **100** is provided with a first optical communication device **1** and a second optical communication device **2**. Note that the first optical communication device **1** is an example of the “optical communication device” recited in claims.
- (10) The first optical communication device **1** is arranged in water, such as, e.g., in the sea. Specifically, the first optical communication device **1** is mounted on a fixed body **80** fixed underwater. The fixed body **80** is fixed in water by being installed on the water bottom **90** via a holding member **81**.
- (11) The second optical communication device **2** is arranged in water, such as, e.g., in the sea. Specifically, the second optical communication device **2** is mounted on a moving body **82** that moves underwater. The moving body **82** includes, for example, an AUV (Autonomous Underwater Vehicle).
- (12) In the first embodiment, the underwater optical communication system **100** is configured to be able to perform optical communication between the first optical communication device **1** and the second optical communication device **2** by receiving the communication light emitted from the first optical communication device **1** by the second optical communication device **2** and perform optical

communication between the second optical communication device **2** and the first optical communication device **1** by receiving the communication light emitted from the second optical communication device **2** by the first optical communication device **1**. Note that FIG. **1** illustrates an example in which the second optical communication device **2** is emitting communication light.

(13) In the first embodiment, the moving body **82** travels through the sea to inspect, for example, structures laid on the seabed. The second optical communication device **2** is configured to transmit the inspection result acquired by a detector (not shown) mounted on the moving body **82** to the first optical communication device **1** by communication light. Further, the first optical communication device **1** is configured to receive the inspection result transmitted from the second optical communication device **2** and transmit the received inspection result to a communication device provided on land, a mother ship, or the like. Note that in a case where optical communication is performed between the first optical communication device **1** and the second optical communication device **2**, the optical communication is performed by moving the moving body **82** to the communicable region.

(14) As shown in FIG. **2**, the first optical communication device **1** is provided with a plurality of light-receiving elements **11**. The plurality of light-receiving elements **11** is configured to receive communication light. The plurality of light-receiving elements **11** is provided so as to correspond to a plurality of channels. Although the number of channels is not particularly limited, in the example shown in FIG. **2**, the first optical communication device **1** is provided with twenty-five (25) channels. Therefore, in the example shown in FIG. **2**, the first optical communication device **1** is provided with twenty-five (25) light-receiving elements **11**.

(15) The plurality of light-receiving elements **11** is each configured by, for example, a photomultiplier tube. In this instance, each of the plurality of light-receiving elements **11** includes a photoelectric converter and an electronic multiplier. The photoelectric converter is configured to convert the communication light into electrons. The electronic multiplier is configured to multiply the converted electrons. Further, the plurality of light-receiving elements **11** is arranged in an array. Note that the term “arranged in an array” denotes a concept including “arranged in a row,” “arranged in a matrix,” and the like. In the example shown in FIG. **2**, the plurality of light-receiving elements **11** is arranged in a matrix of 5×5.

(16) Further, the first optical communication device **1** is provided with a plurality of optical fibers **12**. The plurality of optical fibers **12** is configured to guide communication light to the plurality of light-receiving elements **11**. The plurality of optical fibers **12** is provided so as to correspond to the plurality of light-receiving elements **11**. That is, in the example shown in FIG. **2**, twenty-five optical fibers **12** are provided. Further, the plurality of optical fibers **12** each include a light-incident end portion **12a** (light-focusing end portion) for communication light and a light-emission end portion **12b** for communication light.

(17) Here, in the first embodiment, the plurality of light-emission end portions **12b** are each arranged near each of the plurality of light-receiving elements **11**. The plurality of light-emission end portions **12b** are each arranged so as to face the light-receiving surface of each of the plurality of light-receiving elements **11**. Further, the plurality of light-incident end portions **12a** are each configured to be capable of being arranged at a predetermined position in a predetermined direction. The plurality of light-incident end portions **12a** is configured to be capable of being arranged at positions different from each other in predetermined directions different from each other. That is, at least some of the plurality of light-incident end portions **12a** can be arranged at positions different from each other in predetermined directions different from each other. Note that the plurality of light-incident end portions **12a** may be each provided with a small lens for focusing communication light. In this case, communication light can be focused on the light-incident end portion **12a** by the lens, and therefore, it is possible to more reliably perform optical communication.

(18) Further, the first optical communication device **1** is provided with a protection container **13**

(shown by dashed double-dashed lines). The protection container **13** is arranged in water and is configured to accommodate the plurality of light-receiving elements **11**. The protection container **13** is a sealed pressure-resistant container. The protection container **13** is configured to isolate the plurality of light-receiving elements **11** from the external environment. The protection container **13** has, for example, a cylindrical configuration.

(19) The plurality of optical fibers **12** is configured such that the light-emission end portions **12b** are provided inside the protection container **13** and the light-incident end portions **12a** are provided outside the protection container **13** (i.e., underwater). Each of the plurality of light-incident end portions **12a** is configured to be capable of being arranged at a predetermined position in a predetermined direction outside (underwater) the protection container **13**. The plurality of optical fibers **12** is arranged so as to extend from the inside to the outside of the protection container **13** via the insertion portion **13a** of the protection container **13**. The insertion portion **13a** is configured to allow the plurality of optical fibers **12** to be inserted therethrough while maintaining the inner space **13b** of the protection container **13** in a sealed state.

(20) Further, the first optical communication device **1** is provided with light-emission end portion holders **14**. The light emission end portion holders **14** are configured to hold the plurality of light-emission end portions **12b** near the plurality of light-receiving elements **11**. A plurality of light-emission end portion holders **14** is provided so as to correspond to the plurality of light-receiving elements **11** and a plurality of light-emission end portions **12b**. In the example shown in FIG. 2, twenty-five light-emission end portion holders **14** are provided. Each of the plurality of light-emission end portion holders **14** is provided integrally with the light-receiving surface of the plurality of light-receiving elements **11**. Each of the plurality of light-emission end portion holders **14** has an insertion hole **14a**. The insertion hole **14a** is configured to allow the light-emission end portion **12b** to be inserted therethrough. Each of the plurality of light-emission end portions **12b** is configured to be held by the light-emission end portion holder **14** in a state of being inserted into the insertion hole **14a**.

(21) Further, as shown in FIGS. 3A and 3B, the first optical communication device **1** is provided with a light-incident end portion holder **15**. The light-incident end portion holder **15** is configured to hold at least a part of the plurality of light-incident end portions **12a**. The number of the light-incident end portions **12a** held by the light-incident end portion holder **15** is not particularly limited. In the example shown in FIGS. 3A and 3B, an example is shown in which the light-incident end portion holder **15** holds five light-incident end portions **12a**. The light-incident end portion holder **15** is configured to hold the light-incident end portions **12a** such that the light-incident end portions **12a** are arranged in predetermined directions.

(22) In a case where the directivity of light received by the light-receiving elements **11** (in a case where it is desired to receive communication light in a wide range), for example, the light-incident end portions **12a** can be arranged like the arrangement example shown in FIG. 3A. In the example shown in FIG. 3A, at least some of the plurality of light-incident end portions **12a** are arranged in directions different from each other. Further, in a case where the directivity of light received by the light-receiving elements **11** is decreased (in a case where it is desired to receive communication light from a particular direction), for example, the light-incident end portions **12a** can be arranged like the arrangement example shown in FIG. 3B. In the embodiment shown in FIG. 3B, at least some of the plurality of light-incident end portions **12a** are arranged in the same direction.

(23) (Usage Example of Optical Communication Device)

(24) Next, with reference to FIG. 4, the usage example of the first optical communication device **1** in water will be described.

(25) As shown in FIG. 4, at least some of the plurality of light-incident end portions **12a** are arranged at different positions in water. The number of arrangement positions of the light-incident end portions **12a** is not particularly limited. But, in the example shown in FIG. 4, an example is shown in which the plurality of light-incident end portions **12a** is arranged at five positions

different from each other. In this instance, the moving body **82** can perform optical communication at five positions different from each other.

(26) Further, at least some of the plurality of light-incident end portions **12a** are attached to underwater structures **83**. The underwater structure **83** is not specifically limited, and may be, for example, a column, a rod, a wall, etc. As the underwater structure **83**, a structure may be provided for the first optical communication device **1**, or an existing structure may be used. The light-incident end portion **12a** is attached to the underwater structure **83** via a fixture.

Effects of First Embodiment

(27) In the first embodiment, the following effects can be obtained.

(28) In the first embodiment, as described above, the first optical communication device **1** is provided with a plurality of optical fibers **12** for guiding communication light to the plurality of light-receiving elements **11**. Each of the plurality of optical fibers **12** is configured to include the light-incident end portion **12a** for communication light and the light-emission end portion **12b** for communication light. Each of the plurality of light-emission end portions **12b** is arranged near each of the plurality of light-receiving elements **11**. Each of the plurality of light-incident end portions **12a** is configured to be capable of being arranged at a predetermined position in a predetermined direction. With this, by using the optical fibers **12**, it is possible to arbitrarily select the installation location where each of the plurality of light-receiving elements **11** is installed. Further, by adjusting the positions and the directions of the plurality of light-incident end portions **12a**, it is possible to freely adjust the directivity of light received (the light-receiving direction, the light-receiving range, etc.) by each of the plurality of light-receiving elements **11**. Therefore, it is possible to arbitrarily set the directivity of light received by the plurality of light-receiving elements **11** as a whole.

Further, as a method for realizing an arbitral light-receiving directivity, unlike the case of adopting a method in which a black paper is arranged in front of the light-receiving elements or a method in which a digital mirror device is used, the part of the light incident to the light-receiving elements will not be shielded, and therefore, the sensitivities of the light-receiving elements do not deteriorate. Consequently, it is possible to arbitrarily set the directivities of light received by a plurality of light-receiving elements while maintaining all of the sensitivities of the plurality of light-receiving elements.

(29) Further, in the first embodiment, as described above, the first optical communication device **1** is configured to include the protection container **13** to be arranged in water for accommodating the plurality of light-receiving elements. With this, the plurality of light-receiving elements **11** is accommodated in a single protection container **13**. Therefore, unlike the case of arranging a plurality of light-receiving elements **11** in the plurality of protection containers **13** in a dispersed manner, cables (power cables, signal cables, etc.) used for the plurality of light-receiving elements **11** can be organized into one cable, and the number of protection containers **13** can be reduced. Further, the total weight can also be reduced. Further, since the light-incident end portion **12a** is small and light, it can be installed in a place where it is difficult to arrange the protection container **13**. For this reason, the light-incident end portions **12a** can be densely arranged in one place to improve the sensitivities. These effects are particularly effective when optical communication is performed in water. The plurality of optical fibers **12** is configured such that the light-emission end portions **12b** are provided inside the protection container **13** and the light-incident end portions **12a** are provided outside the protection container **13**. With this, even in a case where the plurality of light-receiving elements **11** are accommodated in the protection container **13**, the plurality of light-incident end portions **12a** of the optical fibers **12** can be arranged at any positions in any directions outside the protection container **13**. Therefore, it is possible to easily ensure the flexibility of adjusting the directivities of light received by the plurality of light-receiving elements **11**.

(30) Further, in the first embodiment, as described above, at least some of the plurality of light-incident end portions **12a** are arranged at positions different from each other in water. With this, since communication light can be received at positions different from each other in water, even

without providing a plurality of optical communication devices, it is possible to perform optical communication at positions different from each other in water by only a single first optical communication device **1**. Consequently, as compared with the case in which a plurality of optical communication devices is provided, underwater optical communication can be performed more easily.

(31) Further, in this embodiment, as described above, the light-incident end portions **12a** are configured to receive communication light from the moving body **82** that moves in water. With this, the moving body **82** can perform optical communication at any positions out of positions different from each other in water, and therefore, underwater optical communication with the moving body **82** can be easily performed.

(32) Further, in the first embodiment, as described above, at least some of the plurality of light-incident end portions **12a** are attached to underwater structures **83**. With this, the light-incident end portions **12a** can be fixed to the underwater structures **83**, so that the positions of the light-incident end portions **12a** can be fixed at the fixed positions. Consequently, as compared with the case in which the positions of the light-incident end portions **12a** are not fixed in place, underwater optical communication can be performed more easily. Further, by using an existing underwater structure **83**, there is no need to prepare an additional structure for fixing.

(33) Further, in the first embodiment, as described above, a plurality of light-receiving elements **11** is arranged in an array. With this, the light-receiving elements **11** can be aligned inside the protection container **13**, and therefore, the light-receiving elements **11** can be compactly accommodated inside the protection container **13**.

(34) Further, in the first embodiment, as described above, the first optical communication device **1** is configured to include light-emission end portion holders **14** for holding the plurality of light-emission end portions **12b** near the plurality of light-receiving elements **11**. With this, the position of the light-emission end portion **12b** can be held, and therefore, it is possible to hold the relative position between the light-emission end portion **12b** and the light-receiving element **11**. Consequently, it is possible to accurately receive communication light from the light-emission end portion **12b** by the light-receiving element **11**.

Second Embodiment

(35) Next, with reference to FIG. 5, a second embodiment of the present invention will be described. In the second embodiment, an example will be described in which in addition to the above-described configuration of the first embodiment, a lens and a lens holder are further provided. Note that the same reference numeral is allotted to the same configuration as that of the first embodiment in the drawings, and the description thereof will be omitted.

(36) (Configuration of First Optical Communication Device)

(37) In a second embodiment, a first optical communication device **101** differs from the first optical communication device **1** of the first embodiment in that the device is further provided with a lens **16** and a lens holder **17**, as shown in FIG. 5. Note that the first optical communication device **101** is an example of the “optical communication device” recited in claims.

(38) The lens **16** is configured to focus communication light on the light-incident end portion **12a** of the optical fiber **12**. The lens **16** is provided at the light-incident surface of the light-incident end portion **12a** so as to face in the A-direction.

(39) The lens holder **17** is provided at the light-incident end portion **12a** and is configured to hold the lens **16**. The light-incident end portion **12a**, the lens **16**, and the lens holder **17** of the optical fiber **12** are configured to be arranged in water (in the sea).

(40) The lens holder **17** includes a main body **17a**, a support portion **17b**, a light-incident opening **17c**, and a water introduction portion **17d**.

(41) The main body **17a** has a columnar shape extending along the A-direction. Specifically, the main body **17a** has a cylindrical shape. More specifically, the main body **17a** has a hollow cylindrical shape. The main body **17a** has an insertion opening (not shown) for inserting the light-

incident end portion **12a** of the optical fiber **12** into the inside of the main body **17a** at the end portion in the A1-direction. The main body **17a** is configured to hold the light-incident end portion **12a** of the optical fiber **12** inserted therein through the insertion opening. Further, the main body **17a** has a light-incident opening **17c** at the end portion in the A2-direction.

(42) The support portion **17b** is configured to support the lens **16**. The support portion **17b** is provided so as to protrude in the A2-direction from the end portion of the main body **17a** in the A2-direction. The support portion **17b** is configured to support the lens **16** at a position spaced apart in the A2 direction from the end portion of the main body portion **17a** in the A2-direction. Therefore, between the lens **16** and the main body **17a** (the light-incident opening **17c**) in the A-direction, a space **18** is formed. A plurality of (four in FIG. 5) support portions **17b** is provided.

(43) The light-incident opening **17c** is configured to allow the communication light focused by the lens **16** to enter into the inside of the main body **17a**.

(44) Here, in the second embodiment, the lens holder **17** has a configuration in which water enters between the light-incident end portion **12a** and the lens **16**. That is, the lens holder **17** is provided with water introduction portions **17d** capable of introducing the surrounding water (such as, e.g., seawater), the water introduction portion **17d** being provided between the light-incident end portion **12a** (light-incident opening **17c**) and the lens **16**. Specifically, the water introduction portion **17d** is provided so as to communicate the surroundings with the space **18**. The water introduction portion **17d** is configured to introduce water between the light-incident end portion **12a** (the light-incident opening **17c**) and the lens **16** by introducing water from the surrounding into the space **18**, when placed in water. The water introduction portion **17d** is provided between the support portion **17b** and the support portion **17b** arranged adjacent to each other. A plurality of (four in FIG. 5) water introduction portions **17d** is provided.

(45) In the second embodiment, the lens holder **17** has a structure considering the refractive index of water. Specifically, the lens holder **17** is configured to hold the lens **16** in a position considered based on the refractive index of water. That is, the lens holder **17** is configured to hold the lens **16** at a position (a position spaced from the light-incident end portion **12a**) farther in the A2-direction, as compared with the case in which the refractive index of air is considered. That is, the lens holder **17** is formed to be larger in the separation distance in the A-direction between the light-incident end portion **12a** and the lens **16** than the separation distance in the A-direction between the light-incident end portion **12a** and the lens **16** when assuming the refractive index of air. With this, it is possible to correctly focus the communication light on the position of the light-incident end portion **12a** even in water.

(46) The rest of the configuration of the second embodiment is the same as that of the first embodiment.

Effects of Second Embodiment

(47) In the second embodiment, the following effects can be obtained.

(48) In the second embodiment, as described above, the first optical communication device **101** is configured such that it is provided with a lens **16** for focusing the communication light on the light-incident end portion **12a** and a lens holder **17** for holding the lens **16**, the lens holder **17** being provided to the light-incident end portion **12a**. Further, the light-incident end portion **12a**, the lens **16**, and the lens holder **17** are configured to be arranged in water. The lens holder **17** is configured to include the water introduction portion **17d** capable of introducing surrounding water, the water introduction portion **17d** being provided between the light-incident end portion **12a** and the lens **16**. With this, even in the case of arranging the light-incident end portion **12a**, the lens **16**, and the lens holder **17** in water, there is no need to make the lens holder **17** a pressure-resistant structure (structure that withstands water pressure). Therefore, as compared with the case of making the lens holder **17** a pressure-resistant structure, it is possible to reduce the size and weight of the lens holder **17**.

(49) Note that other effects of the second embodiment are the same as those of the first

embodiment.

Modifications

(50) It should be understood that the embodiments disclosed here are examples in all respects and are not restrictive. The scope of the present invention is shown by claims rather than the descriptions of the embodiments described above, and includes all changes (modifications) within the meaning and scope equivalent to the claims.

(51) For example, in the above-mentioned first and second embodiments, an example is shown in which the optical communication device is used in the sea, but the present invention is not limited thereto. For example, the optical communication device may be used in water (a lake, a dam, etc.) other than undersea. Further, the optical communication device may also be used in environments (on land) other than underwater.

(52) Further, in the above-mentioned first and second embodiments, an example is shown in which the light-receiving element is configured by a photomultiplier tube, but the present invention is not limited thereto. For example, the light-receiving element may be configured by an avalanche photodiode.

(53) Further, in the first and second embodiments, an example is shown in which the optical communication device is provided with the light-incident end portion holder, but the present invention is not limited thereto. In the present invention, the optical communication device is not required to include a light-incident end portion holder. In this case, for example, the plurality of light-incident end portions may be attached to mounting objects, such as, e.g., underwater structures, so as to be arranged in predetermined directions.

(54) Further, in the first and second embodiments described above, an example is shown in which at least some of the plurality of light-incident end portions are arranged in water at positions different from each other, but the present invention is not limited thereto. For example, all of the plurality of light-incident end portions may be arranged at one location in the water.

(55) Further, in the first and second embodiments described above, an example is shown in which at least some of the plurality of light-incident end portions are attached to underwater structures other than fixed bodies, but the present invention is not limited thereto. For example, at least some of the plurality of light-incident end portions may be attached to a fixed body, a protection container, or the like.

(56) Further, in the above-mentioned first and second embodiments, an example is shown in which communication light from a moving body moving in the water is incident on the light-incident end portion, but the present invention is not limited thereto. For example, the communication light from another fixed body may be incident on the light-incident end portion.

(57) Further, in the above-mentioned first and second embodiments, an example is shown in which the optical communication device is mounted on the fixed body fixed in water, but the present invention is not limited thereto. For example, the optical communication device may be provided on a moving body that moves through the water. In this instance, at least some of the plurality of light-incident end portions may be arranged at positions of the moving body different from with each other, or all of the plurality of light-incident end portions may be arranged at a single location of a moving body.

(58) Further, in the first and second embodiments, an example is shown in which the plurality of light-receiving elements is accommodated in a single protection container, but the present invention is not limited thereto. In the present invention, a plurality of light-receiving elements may be accommodated in a plurality of protection containers in a distributed manner. However, from the viewpoint of simplifying the configuration of the optical communication device, it is preferable that a plurality of light-receiving elements be accommodated in a single protection container.

(59) Further, in the first and second embodiment examples, an example is shown in which a plurality of light-receiving elements is arranged in an array, but the present invention is not limited thereto. For example, a plurality of light-receiving elements may be arranged in a distributed

manner.

(60) Further, in the first and second embodiments described above, an example is shown in which a plurality of light-emission end portion holders is provided, but the present invention is not limited thereto. For example, the light-emission end portion holder may be a single member that holds a plurality of light-emission end portions.

(61) Further, in the first and second embodiments described above, an example is shown in which the moving body is an AUV (Autonomous Underwater Vehicle), but the present invention is not limited thereto. For example, the moving body may be a HOV (Human Occupied Vehicle). Further, the moving body may be a remotely controlled robot (ROV: Remotely Operated Vehicle) operated by a person via a cable. Further, the moving body may be a ship other than the above.

Aspects

(62) It will be understood by those skilled in the art that the above-described exemplary embodiments are concrete examples of the following aspects.

Item 1

(63) An optical communication device comprising: a plurality of light-receiving elements configured to receive communication light, the plurality of light-receiving elements being provided so as to correspond to a plurality of channels; and a plurality of optical fibers configured to guide the communication light to the plurality of light-receiving elements, the plurality of optical fibers being provided so as to correspond to the plurality of light-receiving elements, wherein the plurality of optical fibers each includes a light-incident end portion for the communication light and a light-emission end portion for the communication light, wherein the plurality of light-emission end portions is each arranged near each of the plurality of light-receiving elements, and wherein the plurality of the light-incident end portions is each configured to be capable of being arranged at a predetermined position in a predetermined direction.

Item 2

(64) The optical communication device as recited in the above-described Item 1, further comprising: a protection container configured to accommodate the plurality of light-receiving elements, the protection container being configured to be arranged in water, wherein the plurality of optical fibers is each configured such that the light-emission end portion is provided inside the protection container and the light-incident end portion is provided outside the protection container.

Item 3

(65) The optical communication device as recited in the above-described Item 2, wherein at least some of the plurality of light-incident end portions are arranged at positions different from each other in water.

Item 4

(66) The optical communication device as recited in the above-described Item 3, wherein the light-incident end portion is configured such that the communication light from a moving body that moves in water is incident on the light-receiving end portion.

Item 5

(67) The optical communication device as recited in any one of the above-described Items 2 to 4, wherein at least some of the plurality of light-incident end portions are attached to underwater structures.

Item 6

(68) The optical communication device as recited in any one of the above-described Items 2 to 5, wherein the plurality of light-receiving elements is arranged in an array.

Item 7

(69) The optical communication device as recited in any one of the above-described Items 1 to 6, further comprising: a light-emission end portion holder configured to hold each of the plurality of light-emission end portions near each of the plurality of light-receiving elements.

Item 8

(70) The optical communication device as recited in any one of the above-described Items 1 to 7, further comprising: a lens configured to focus the communication light on the light-incident end portion; and a lens holder configured to hold the lens, the lens holder being provided at the light-incident end portion, wherein the light-incident end portion, the lens, and the lens holder are configured to be arranged in water, and wherein the lens holder includes a water introduction portion capable of introducing surrounding water, the water introduction portion being provided between the light-incident end portion and the lens.

DESCRIPTION OF SYMBOLS

(71) **1, 101**: First optical communication device (optical communication device) **11**: Light-receiving element **12**: Optical fiber **12a**: Light-incident end portion **12b**: Light-emission end portion **13**: Protection container **14**: Light-emission end portion holder **16**: Lens **17**: Lens holder **17d**: Water introduction portion **82**: Moving body **83**: Underwater structure

Claims

1. An optical communication device comprising: a plurality of light-receiving elements configured to receive communication light, the plurality of light-receiving elements being provided so as to correspond to a plurality of channels; and a plurality of optical fibers having a one to one correspondence for each of the light-receiving elements, configured to guide the communication light to the plurality of light-receiving elements, each of the plurality of optical fibers being provided so as to guide communication light to a corresponding one of the plurality of light-receiving elements, wherein each optical fiber of the plurality of optical fibers includes a light-incident end portion for the communication light and a light-emission end portion for the communication light, wherein each light-emission end portion of the plurality of light-emission end portions is arranged so as to face a light-receiving surface of a corresponding light-receiving element of the plurality of light-receiving elements, wherein the plurality of the light-incident end portions is each configured to be capable of being arranged at a predetermined position in a predetermined direction, and wherein the light-incident end portions is configured such that the communication light from a moving body that moves in water is incident on the light-incident end portion.
2. The optical communication device as recited in claim 1, further comprising: a protection container configured to accommodate the plurality of light-receiving elements, the protection container being configured to be arranged in water, wherein the plurality of optical fibers is each configured such that the light-emission end portion is provided inside the protection container and the light-incident end portion is provided outside the protection container.
3. The optical communication device as recited in claim 2, wherein at least some of the plurality of light-incident end portions are arranged at positions different from each other in water.
4. The optical communication device as recited in claim 2, wherein at least some of the plurality of light-incident end portions are attached to underwater structures.
5. The optical communication device as recited in claim 2, wherein the plurality of light-receiving elements is arranged in an array.
6. The optical communication device as recited in claim 1, further comprising: a light-emission end portion holder configured to hold each of the plurality of light-emission end portions near each of the plurality of light-receiving elements.
7. The optical communication device as recited in claim 1, further comprising: a lens configured to focus the communication light on the light-incident end portion; and a lens holder configured to hold the lens, the lens holder being provided to the light-incident end portion, wherein the light-incident end portion, the lens, and the lens holder are configured to be arranged in water, and wherein the lens holder includes a water introduction portion capable of introducing surrounding water, the water introduction portion being provided between the light-incident end portion and the

lens.

8. An optical communication device comprising: a plurality of optical fibers, each optical fiber of the plurality of optical fibers dedicated to a corresponding channel of a plurality of channels and having a light-incident end and a light-emission end; and a plurality of light-receiving elements, each light-receiving element of the plurality of light-receiving elements having a photoelectric converter and dedicated to a respective corresponding channel of the plurality of channels and arranged to receive a communication light transmitted from the light-emission end of an optical fiber dedicated to the channel, and wherein each light incident end of the plurality of optical fibers is arranged at a predetermined position independent from one another and at a predetermined direction independent from one another to receive the communication light from a body moving in water, wherein each light-emission end of the plurality of optical fibers is arranged to face a light receiving surface of a corresponding light-receiving element of the plurality of light-receiving elements to transmit the communication light thereto, and wherein the plurality of optical fibers is configured such that a communication light from a moving body that moves in water is incident on at least one of the light-incident ends.

9. The optical communication device as recited in claim 8, further comprising: a protection container housing the plurality of light-receiving elements, the protection container being configured to be located in water, wherein the plurality of optical fibers is configured such that the light-emission ends are located within the protection container and the light-incident ends are located outside the protection container.

10. The optical communication device as recited in claim 9, wherein at least one light-incident end of the plurality of optical fibers is arranged at a position different than at least one other light-incident end of the plurality of optical fibers.

11. The optical communication device as recited in claim 9, wherein at least one light-incident end of the plurality of optical fibers is attached to an underwater structure.

12. The optical communication device as recited in claim 9, wherein the plurality of light-receiving elements is arranged as an array of light-receiving elements.

13. The optical communication device as recited in claim 8, further comprising: a light-emission end holder configured to hold each light-emission end of the plurality of optical fibers near a corresponding light-receiving element of the plurality of light-receiving elements.

14. The optical communication device as recited in claim 8, further comprising: a lens configured to focus a communication light on a light-incident end of an optical fiber of the plurality of optical fibers; and a lens holder configured to hold the lens and being secured to the light-incident end, wherein the light-incident end, the lens, and the lens holder are configured to be located in water, and wherein the lens holder includes a water introduction portion for introducing surrounding water, the water introduction portion being provided between the light-incident end and the lens.
