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(54) Title: MULTIPLE FILTER PACKAGE CONFIGURATION FOR WAVELENGTH DIVISION MULTIPLEXER

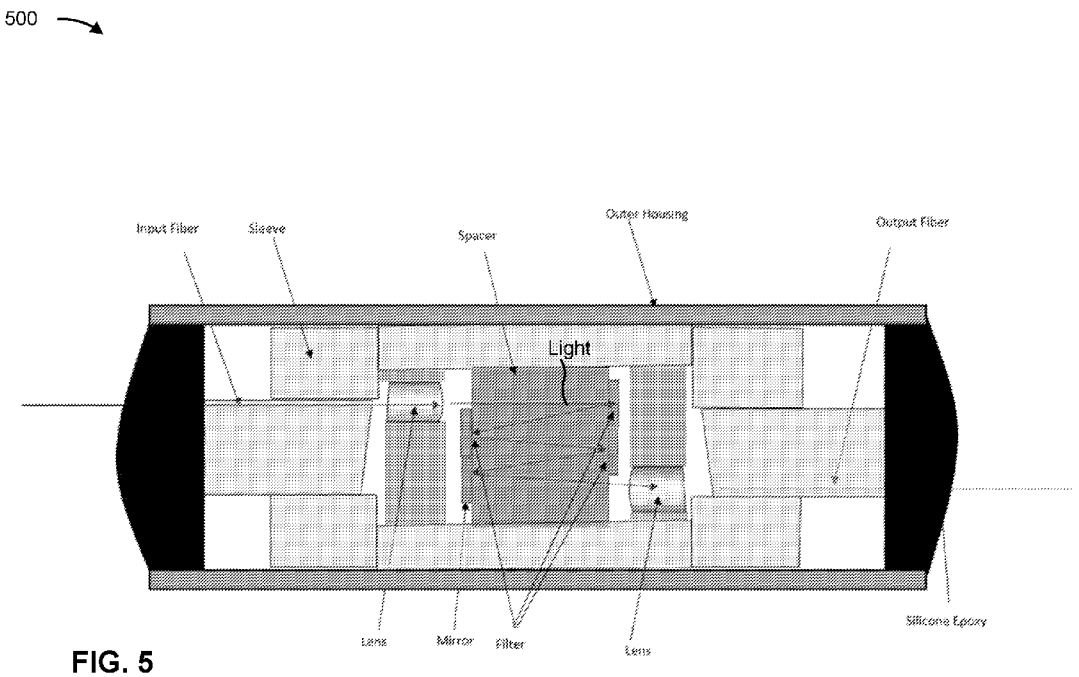

FIG. 5

(57) Abstract: A method, device, system, apparatus, a package, an optical device, an Erbium-doped fiber amplifier (EDFA), and a wavelength division multiplexer (WDM) as substantially described herein.

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MULTIPLE FILTER PACKAGE CONFIGURATION FOR WAVELENGTH DIVISION MULTIPLEXER

BACKGROUND

[0001] Erbium-doped fiber amplifiers (EDFAs) are an important enabling technology for optical communication. In some cases, an EDFA use a two-port wavelength division multiplexer (WDM), which passes one wide wavelength band (a "pass band") and reflects another, adjacent wide wavelength band (a "reflect band"). However, when a gap between the pass band and the reflect band is small, a single filter cannot be used in the WDM. A gap is small when, for example, the gap is less than 3% of a width of the passband. For example, for a 17.5 nanometer (nm) width passband filter (e.g., that passes light associated with 1500-1517.5 nm), a gap is small when it is less than 0.5 nm (e.g., less than 3% of the width of the passband filter).

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Fig. 1 illustrates an example package configuration 100 that shows an input fiber and an output fiber positioned on a same side of an optical device.

[0003] Fig. 2 illustrates an example package configuration 200 that shows an input fiber and an output fiber positioned on opposite sides of an optical device.

[0004] Fig. 3 illustrates an example package configuration 300 that shows an input fiber and an output fiber positioned on opposite sides of an optical device.

[0005] Fig. 4 illustrates an example package configuration 400 that shows an input fiber and an output fiber positioned on opposite sides of an optical device.

[0006] Fig. 5 illustrates an example package configuration 500 that shows an input fiber and an output fiber positioned on opposite sides of an optical device.

[0007] Fig. 6 illustrates an optical device including three filters that pass a wide wavelength band and reflect another wide wavelength range in a narrow band.

DETAILED DESCRIPTION OF THE INVENTION

[0008] Some implementations described herein provide an optical device that may include multiple filters (e.g., in a cascading formation) that may be arranged with optical components, such as a lens, a spacer, and/or other optical components. A quantity of the multiple filters may be configured to provide a particular optical performance (e.g., to satisfy a particular optical performance requirement). In some implementations, the optical device may include a mirror (e.g., as shown in Figs. 1, 2, and 5). The multiple filters and the mirror may be included in an "optical block" of the optical device that is positioned within a housing (e.g., a cylindrical housing) of the optical device.

[0009] Example package configurations for an optical device (e.g., a WDM of an EDFA) are shown in Figs. 1-5 (e.g., that show different fiber positions). Fig. 1 illustrates an example package configuration 100 that shows an input fiber and an output fiber positioned on a same side of an optical device. As further shown in Fig. 1, the optical device may include two filters and a mirror (e.g., for filtering and directing light from the input fiber to the output fiber, such as via a geometric optical path). Fig. 2 illustrates an example package configuration 200 that shows an input fiber and an output fiber positioned on opposite sides of an optical device. As further shown in Fig. 2, the optical device may include three filters and a mirror (e.g., for filtering and directing light from the input fiber to the output fiber, such as via a geometric optical path). The package configuration 200 may provide a wide block range (e.g., greater than 100 nm). Fig. 3 illustrates an example package configuration 300 that shows an input fiber and an output fiber positioned on opposite sides of an optical device. As further shown in Fig. 3, the optical device may include two filters (e.g., for filtering and directing light from the input fiber to the output fiber, such as via a geometric optical path). The package configuration 300 may provide a block range of approximately 40 nm (e.g., within a tolerance, such as 4 nm).

[0010] Fig. 4 illustrates an example package configuration 400 that shows an input fiber and an output fiber positioned on opposite sides of an optical device. As further shown in Fig. 4, the optical device may include two filters, two lenses, and a spacer (e.g., for filtering and directing light from the input fiber to the output fiber) that are positioned within an outer housing (e.g., a cylindrical housing) of the optical device. As further shown in Fig. 4, light may emit from the input fiber to a first lens (e.g., falling incident on the first lens with an angle of incidence that is less than or equal to 3 degrees), which may direct (via the spacer) the light to a first filter, which may filter and direct (e.g., via the spacer) the light to a second filter, which may filter and direct (e.g., via the spacer) the light to a second lens, which may direct the light to the output fiber.

[0011] Fig. 5 illustrates an example package configuration 500 that shows an input fiber and an output fiber positioned on opposite sides of an optical device. As further shown in Fig. 5, the optical device may include three filters, a mirror, two lenses, and a spacer (e.g., for filtering and directing light from the input fiber to the output fiber) that are positioned within an outer housing (e.g., a cylindrical housing) of the optical device. As further shown in Fig. 5, light may emit from the input fiber to a first lens (e.g., falling incident on the first lens with an angle of incidence that is less than or equal to 3 degrees), which may direct (via the spacer) the light to a first filter, which may filter and direct (e.g., via the spacer) the light to a second filter, which may filter and direct (e.g., via the spacer) the light to a third filter, which may filter and direct (e.g., via the spacer) the light to a mirror, which may direct (e.g., via the spacer) the light to a second lens, which may direct the light to the output fiber.

[0012] In this way, some implementations described herein resolve challenging design requirements of EDFAs. For example, some optical devices described herein pass a wide wavelength band and reflect another wide wavelength range in a narrow band. In a particular example, an optical device described herein (e.g., that includes three filters) can pass light

associated with a 970-995 nm band and 1500-1517.5 nm band and reflect light associated with a 1518-1670 nm band. A first filter of the optical device reflects light associated with a 1518-1520 nm band and passes light associated with the 970-995 nm band and the 1500-1517.5 nm band; a second filter of the optical device reflects light associated with a 1520-1540 nm band and passes light associated with the 970-995 nm band and the 1500-1517.5 nm band; and a third filter of the optical device reflects light associated with a 1540-1670 nm and passes light associated with the 970-995 nm band and the 1500-1517.5 nm band. This concept is illustrated in Fig. 6. Further, other optical devices described herein (e.g., that include two filters, four filters, and so on) can pass light associated with a 970-995 nm band and 1500-1517.5 nm band and reflect light associated with a 1518-1670 nm band. Thus, the optical devices described herein provide an optical performance that cannot be achieved using a single WDM filter design (e.g., because a gap between the 1500-1517.5 nm pass band and the 1518-1670 nm band is 0.5 nm).

[0013] The foregoing disclosure provides illustration and description, but is not intended to be exhaustive or to limit the implementations to the precise form disclosed. Modifications may be made in light of the above disclosure or may be acquired from practice of the implementations.

[0014] Although particular combinations of features are recited in the claims and/or disclosed in the specification, these combinations are not intended to limit the disclosure of various implementations. In fact, many of these features may be combined in ways not specifically recited in the claims and/or disclosed in the specification. Although each dependent claim listed below may directly depend on only one claim, the disclosure of various implementations includes each dependent claim in combination with every other claim in the claim set.

[0015] No element, act, or instruction used herein should be construed as critical or essential unless explicitly described as such. Also, as used herein, the articles "a" and "an" are intended to include one or more items, and may be used interchangeably with "one or more." Further, as used herein, the article "the" is intended to include one or more items referenced in connection with the article "the" and may be used interchangeably with "the one or more." Furthermore, as used herein, the term "set" is intended to include one or more items (e.g., related items, unrelated items, a combination of related and unrelated items, etc.), and may be used interchangeably with "one or more." Where only one item is intended, the phrase "only one" or similar language is used. Also, as used herein, the terms "has," "have," "having," or the like are intended to be open-ended terms. Further, the phrase "based on" is intended to mean "based, at least in part, on" unless explicitly stated otherwise. Also, as used herein, the term "or" is intended to be inclusive when used in a series and may be used interchangeably with "and/or," unless explicitly stated otherwise (e.g., if used in combination with "either" or "only one of").

WHAT IS CLAIMED IS:

1. A method, device, system, apparatus, a package, an optical device, an Erbium-doped fiber amplifier (EDFA), and a wavelength division multiplexer (WDM) as substantially described herein with reference to and as illustrated by the accompanying drawings and specification.

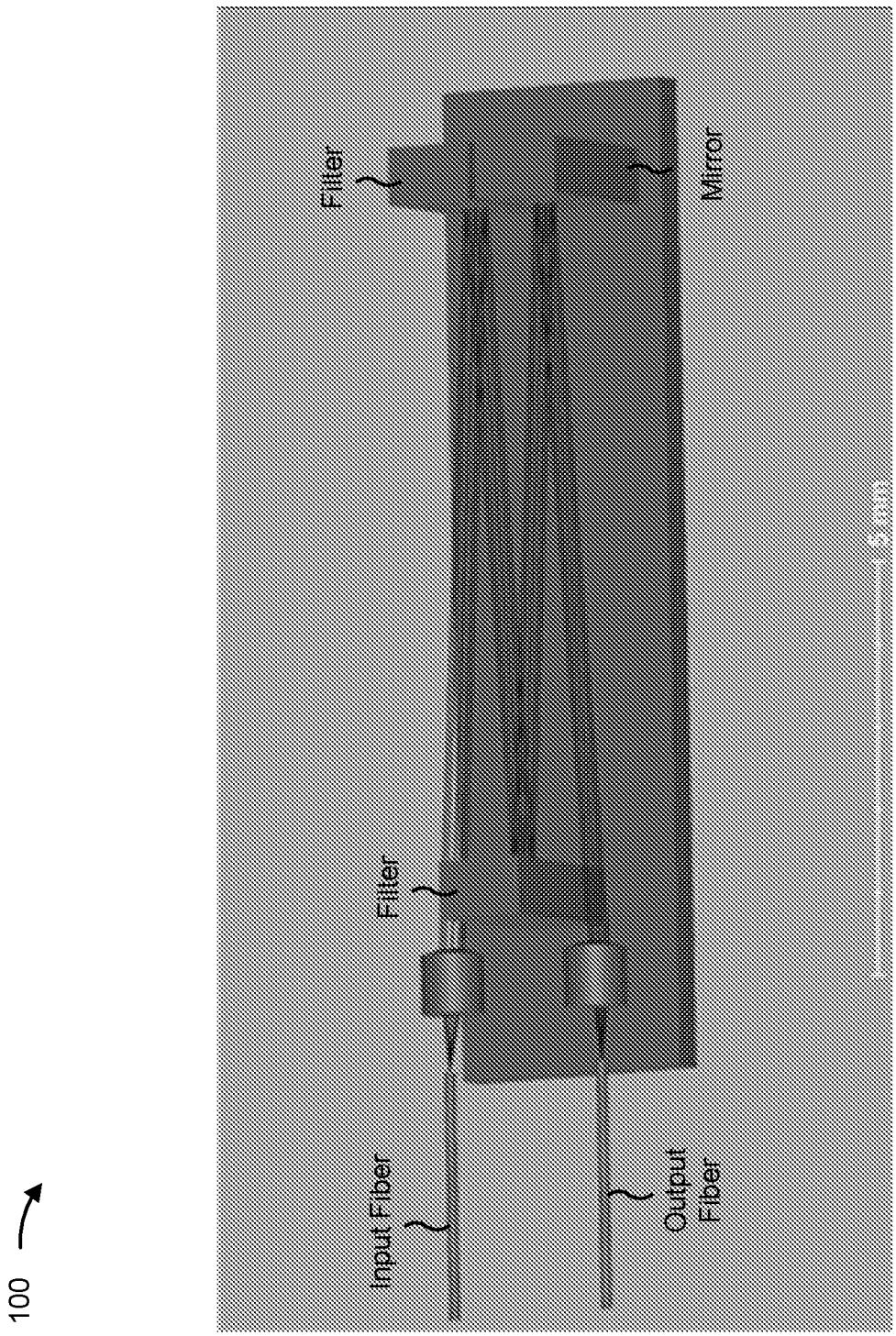

FIG. 1

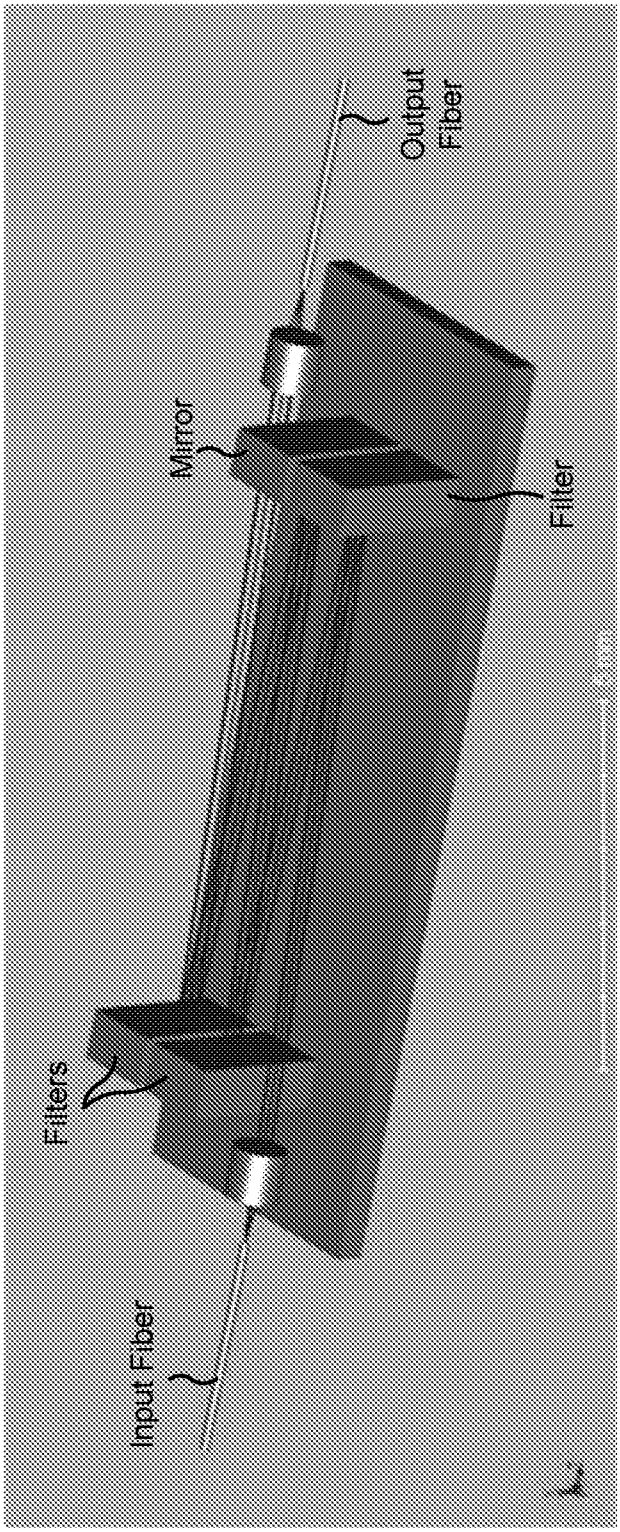

FIG. 2

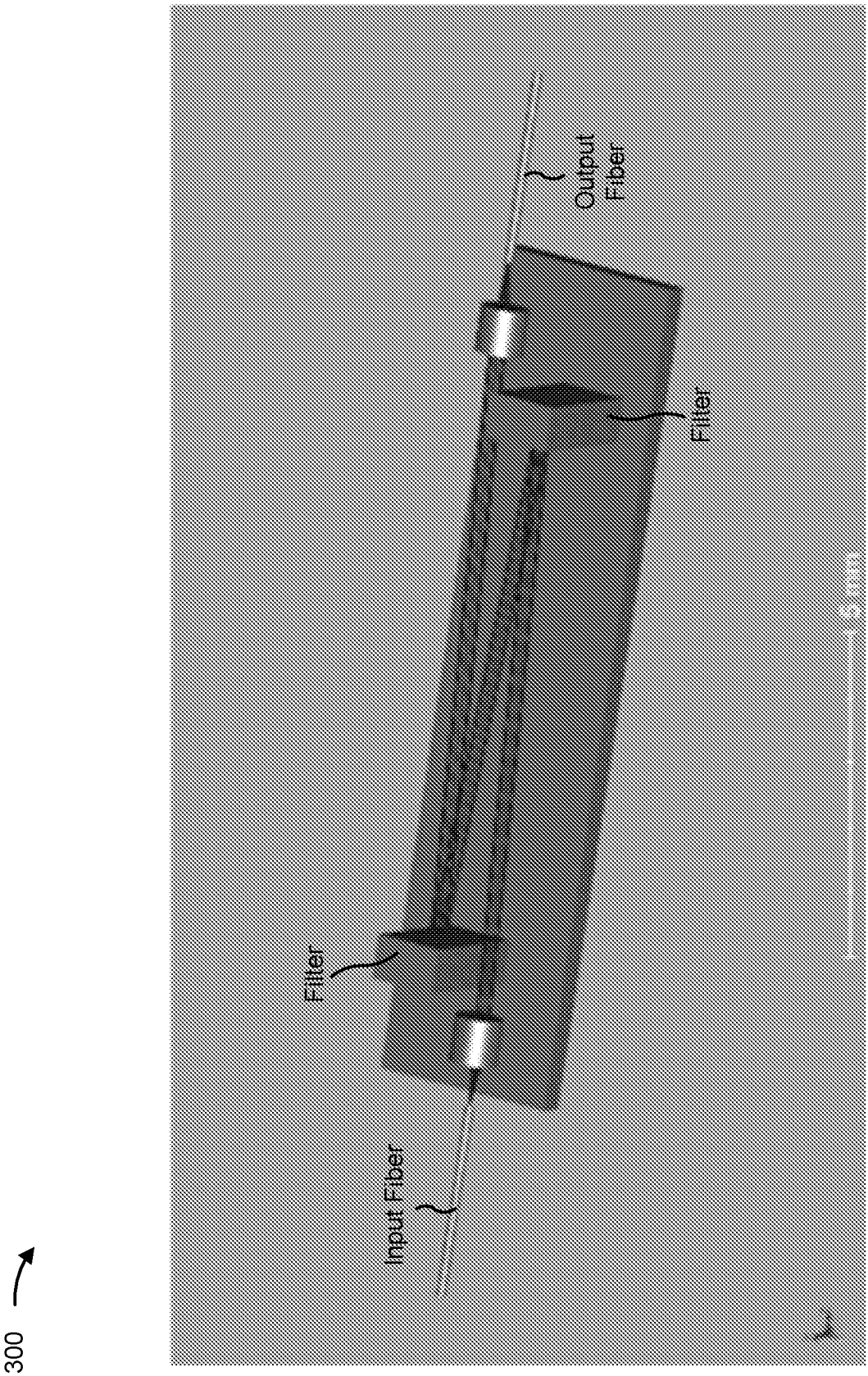

FIG. 3

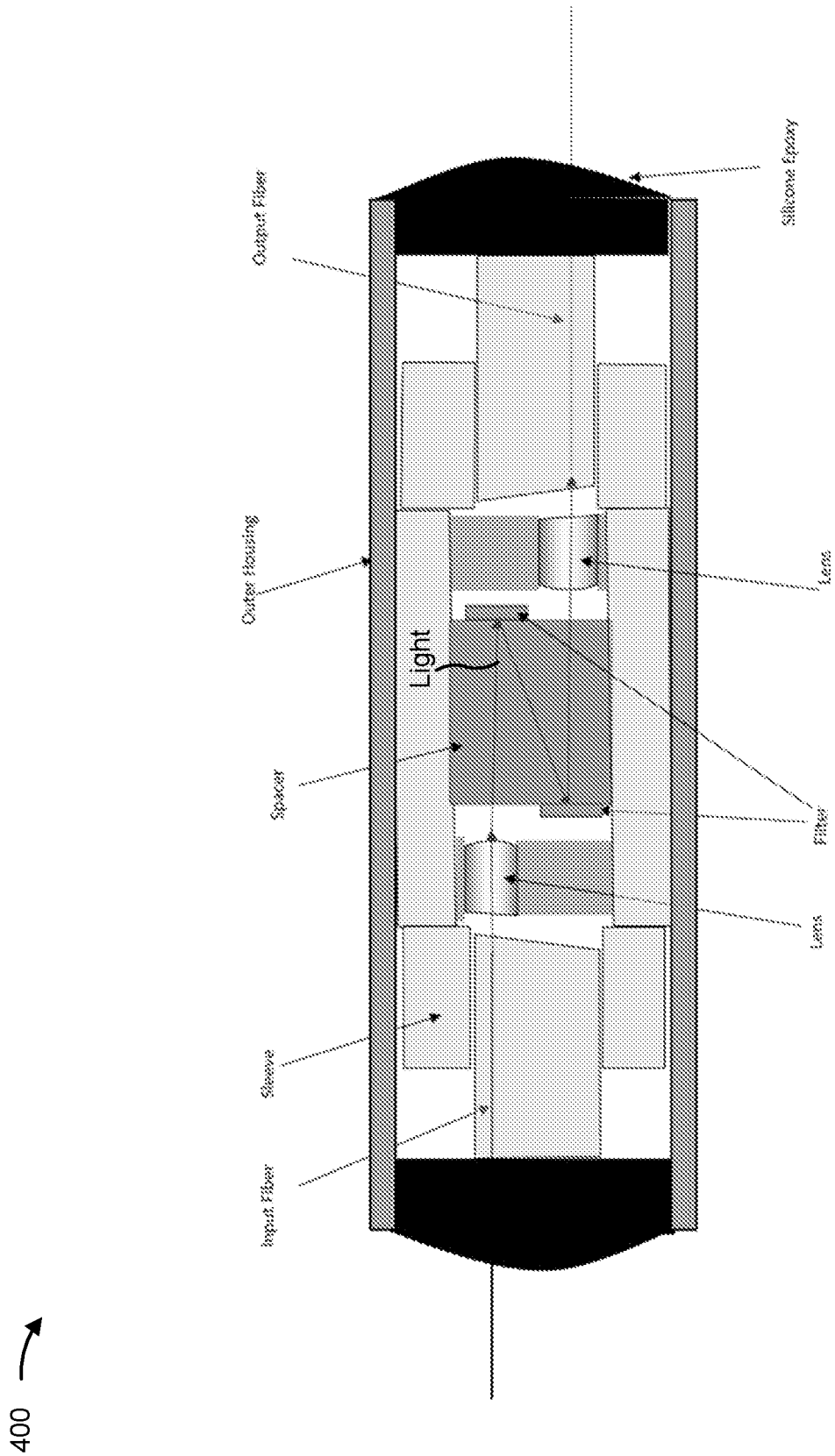
400
Output Fiber
Silicone Epoxy
Outer Housing
Lens
Light
Spacer
Filter
Lens
Sleeve
Input Fiber

FIG. 4

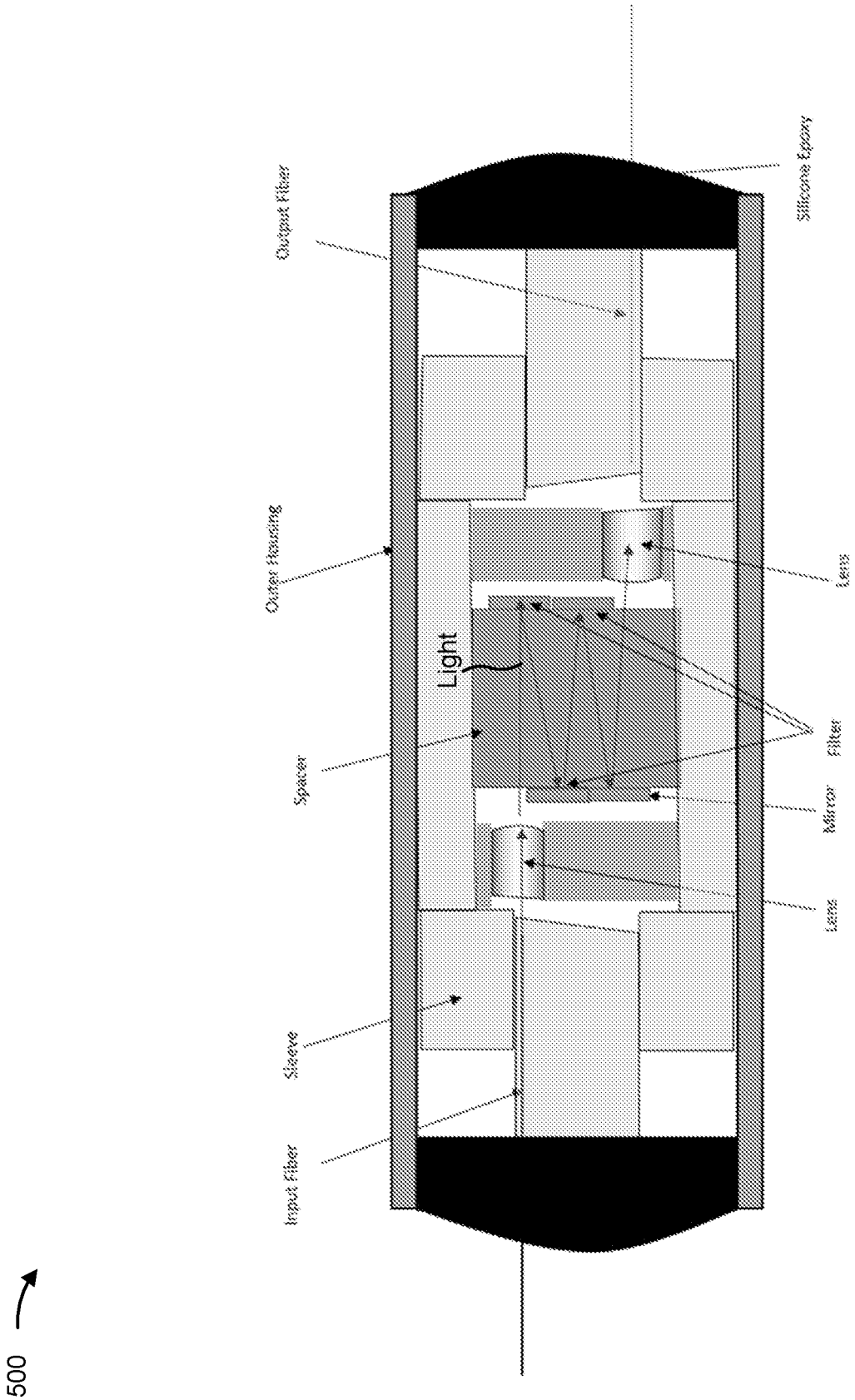
500
Output Fiber
Silicone Epoxy
Outer Housing
Lens
Light
Spacer
Filter
Mirror
Lens
Sleeve
Input Fiber

FIG. 5

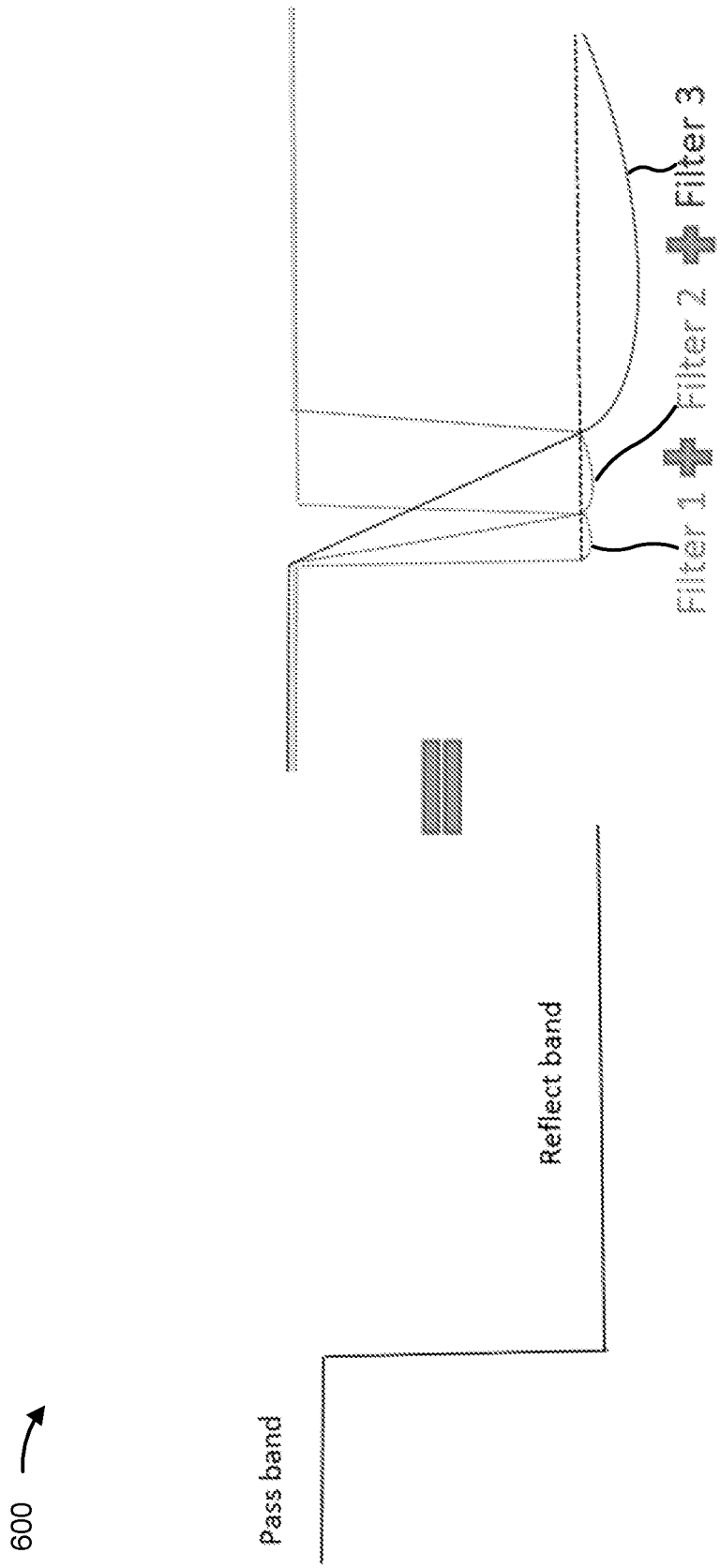

FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2021/136378

A. CLASSIFICATION OF SUBJECT MATTER

H01S 3/101(2006.01)i; G02B 6/32(2006.01)i

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)

H01S G02B G01N H04L 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)

CNPAT, CNKI, WPI, EPODOC: filter, optic+, mirror, lens, spacer, fiber, reflect, conduct, wide, narrow, band, wavelength, gap

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 103067092 A (HUAWEI TECHNOLOGIES CO., LTD.) 24 April 2013 (2013-04-24) description, paragraphs 31-75	1
A	CN 108828730 A (WUHAN TELECOMMUNICATION DEVICES CO., LTD.) 16 November 2018 (2018-11-16) the whole document	1
A	CN 1704780 A (BROWAVE CORPORATION) 07 December 2005 (2005-12-07) the whole document	1
A	CN 102868090 A (WUHAN ACCELINK TECHNOLOGIES CO., LTD.) 09 January 2013 (2013-01-09) the whole document	1
A	US 2017261691 A1 (OPTIWORKS, INC.) 14 September 2017 (2017-09-14) the whole document	1

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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"P" document published prior to the international filing date but later than the priority date claimed
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"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
01 July 2022	**27 July 2022**
Name and mailing address of the ISA/CN **National Intellectual Property Administration, PRC** **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing** **100088, China** Facsimile No. **(86-10)62019451**	Authorized officer **WANG,Jian** Telephone No. **86-(10)-53961733**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2021/136378

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
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				WO	2014101427	A1	03 July 2014
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				US	2014185131	A1	03 July 2014
CN	108828730	A	16 November 2018		None		
CN	1704780	A	07 December 2005		None		
CN	102868090	A	09 January 2013	WO	2014048003	A1	03 April 2014
				US	2015288142	A1	08 October 2015
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