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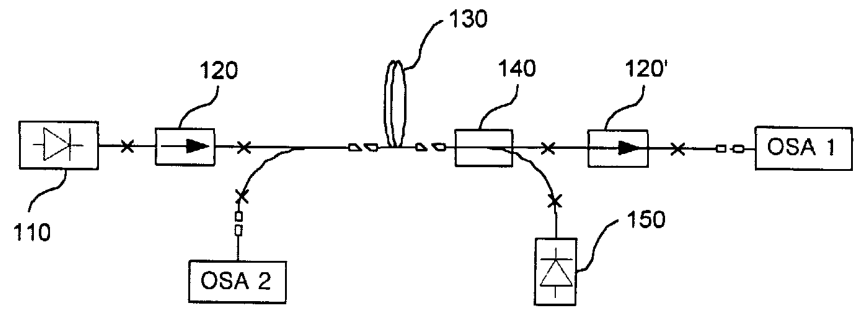
(54) Title: MULTI-CHANNEL LIGHT SOURCE WITH HIGH-POWER AND HIGHLY FLATTENED OUTPUT



(57) **Abstract:** The present invention relates to a multi-channel wide band light source with high-power and highly flattened output which uses stimulated Brillouin scattering, a non-linear effect of an optical fiber, and gain obtained by external pumping. The multi-channel light source of the present invention is characterized in that multi-channel of an equal wavelength spacing is created by continuous stimulated Brillouin scattering and the light source produces a high power output beam by gain-produced optical amplification and Rayleigh scattering at its medium. According to the present invention, it is possible to create a multi-channel output beam having a channel number corresponding to the gain bandwidth by applying stimulated Brillouin scattering and pump-induced gain to the medium of the light source.

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MULTI-CHANNEL LIGHT SOURCE WITH HIGH-POWER AND HIGHLY FLATTENED OUTPUT

Technical Field

The present invention relates to a light source, and more particularly, to a high power and wideband multi-channel laser light source.

Background Art

A light source, which can generate multi-channel wideband output light having a constant wavelength spacing with the use of continuous Brilliouin scattering induction has been a topic of continous research, with its broad application possibilities including sources in the wavelength division multiplexing systems, frequency standard light source, and light sources for laser gyro sensor or current sensor, as well as all-optical carrier generation in millimeter wave. Especially, a ring-shaped multi-channel Brillouin/Erbium fiber laser (hereinafter referred to as " BEFL") light source using erbium-doped fiber (hereinafter referred to as "EDF") as an amplification medium, and using a single mode fiber as a Brillouin seed, has been considered as the most promising candidate for the multi-channel laser light source owing to its characteristics which enable several tens of channels with high output intensity.

FIG. 1 diagrammatically shows a generic structure of a conventional BEFL multi-channel fiber light source. Referring to FIG. 1, a light emitted from a Brillouin pump light source 10 having a power over a critical value is injected into a ring-shaped structure through a first circulator 20 and a first single mode optical combiner 30, and enters a single mode optical fiber 70. The single mode optical fiber 70 creates a light having an opposite direction and a wavelength transition of an approximately 10 GHz, induced by the Brillouin scattering. The created light is then amplified while passing a first EDF 50 of the ring-shaped structure. A part of the amplified light passes through a second single mode optical combiner 30′ and a second EDF 50′, and is injected into the single mode optical fiber 70, thus again creating a light of which wavelength is shifted by 10 GHz. However, this conventional BEFL fluorescent light source holds drawbacks such as strong polarization dependency, complexity in the structure, and difficulty in finding a proper operation point with the simultaneous control of various parameters. In FIG. 1, non-described numeral 40 represents a Faraday isolator for inducing a photon generating laser beam in the clockwise direction, and numerals 60 and 60′ represent polarization controller for controlling polarization state of the light passing through the ring-shaped structure.

In addition to the aforementioned drawbacks, the BEFL has drawbacks of complicated structure, polarization dependency, low stability and the like, while its channel count still limited to maximum several tens of channels. However, with the recent need for the generation of stable, simple-structured optical-fiber-base multi-channel light with precise wavelength spacing, it became necessary to develop a new type of high-power, wideband multi-channel laser light source with high stability and simple structure.

Detailed Description of the Invention

Accordingly, it is a technical object of the invention to provide an effective multi-channel light source with high stability and gain flatness.

It is another object of the invention to provide a standard multi-channel light source with precise wavelength spacing.

To accomplish the above technological objects, there is provided a multi-channel light source comprising: a medium having a gain by a non-linear Brillouin scattering effect and a pumping; a pumping means optically coupled to the medium, for irradiating a pumping light so as to generate aforementioned effects; an external light source for introducing its output light thereof so as to generate a multi-wavelength light signal from the medium; and an output means connected to the medium so as to receive the multi-wavelength light signal generated from the medium.

Brief Description of the Drawings

FIG. 1 is a schematic view of a conventional Brillouin/Erbium fiber laser light source;

FIG. 2 is a schematic view of a wideband multi-channel laser light source in accordance with one preferred embodiment of the present invention;

FIG. 3A is an embodied example of the pumping means shown in FIG. 2 and is a schematic view of an induction Raman amplification pump;

FIG. 3B is a graph showing a result measuring an cascaded Raman Stokes wavelength transition of the wideband multi-channel laser according to the pump structure of FIG. 3A at the point "A" of FIG. 3A;

FIG. 4 is a graph showing output spectra of a wideband multi-channel laser in accordance with one preferred embodiment of the present invention;

FIG. 5 is a schematic view of a multi-channel creation mechanism that is necessary for realizing a multi-channel light source of the present invention;

FIG. 6A is a schematic view of a multi-channel laser light source in accordance with another embodiment of the present invention;

FIG. 6B is a schematic view of a ring-shaped multi-channel laser light source in accordance with further another embodiment of the present invention; and

FIG. 7 is a schematic view of a light source to which a means for extracting a wavelength of with a wider spacingis added.

Best Modes for Carrying out the Invention

Hereinafter, preferred embodiments of the present invention are described with reference to the accompanying drawings.

FIG. 2 is a schematic view of a wideband multi-channel laser light source in accordance with one preferred embodiment of the present invention. Referring to FIG. 2, a pumping means 150 is optically coupled to a dispersion compensation fiber 130 corresponding to a medium having gain due to nonlinear stimulated Brillouin scattering effect and pumping, through an optical coupler 140. Meanwhile, a light emited from an external light source 110 for generating a multi-wavelengths light signal at the dispersion compensating fiber 130 enters the dispersion compensating fiber 130 through a first isolator 120. As the external light source 110, an external cavity laser (ECL) can be used. Meanwhile, the multi-wavelengths light signal created from the dispersion compensating fiber 130 is outputted through a second isolator 120′ provided in an output terminal. In FIG. 2, non-described reference symbols OSA1 and OSA2 represent optical signal analyzers, respectively. In the current embodiment, the dispersion compensating fiber 130 with a dispersion value opposite to the dispersion value of conventional single mode fiber was used as the medium providing a gain due to the non-linear stimulated Brillouin scattering effect and pumping, because the dispersion compensating fiber 130 has a small core diameter which effectively induce the non-linear phenomenon strongly. However, any medium can be used if it has an effect of the gain due to the non-linear stimulated Brillouin scattering effect and pumping. Also, it is desirous that the medium is not the medium generating the gain only at any one section but is the distributed gain medium.

Meanwhile, as the pumping means 150, a pump light source having a single wavelength or a plurality of wavelengths can be used. Further, a pumping means of utilizing the cascaded Raman amplification effect described in FIG. 3A can be used. Here, the pump can be installed at any one side of the medium or both sides of the medium, or at a front end or a rear end of the medium.

The multi-channel light source shown in FIG. 2 can be summarized as follows - through the comparison with the BEFL of FIG. 1. The present invention uses the Raman amplification principle having the inhomogeneous gain property as the gain medium, while the BEFL of FIG. 1 uses the EDF amplification having the homogeneous gain property. Also, the present invention utilizes the stimulated Brillouin scattering wavelength created in the Raman amplification medium itself instead of the single mode optical fiber, which was used to create the generation of Brillouin wavelength. In other words, the conventional BEFL realizes the creation of the Brillouin and the amplification separately from each other, while the present invention realizes these two effects from one medium. Also, the present invention employed a medium with a large Rayleigh scattering effect, which helps naturally to form a lasing cavity structure.

The pumping means 150 of FIG. 2, a cascaded Raman amplification pump is embodied in as an example, and the structure is shown in FIG. 3A. Referring to FIG. 3A, an ytterbium (Yb) optical fiber laser pump light source 300, and high-power laser diode pump light sources 310 and 320 having an output light of 1465 nm and an output light of 1480 nm, respectively are connected through a pump combiner 330, and they can be used together. Meanwhile, the ytterbium optical fiber laser pump light source 300 is connected to a pump combiner together with a mirror 340 for returning a reflected light. In order to create a multi-channel at 1500 nm band, it is basically needed to provide a strong pump at 1400 nm band since Raman transition in the 1500 nm band is approximately 100 nm or so. At present, since the semiconductor lasers having strong power in the bandwidth of 1400 nm have a maximum power level only up to several hundred mW, usually one uses a five to six times of Stokes transitions of a high power light source at 1060nm to 1400nm with the use of optical fiber grating and cascaded Raman Stokes generation in order to create the W-grade power at 1400 nm band. In FIG. 3A, two wavelength division combiners are used so as to inject the power of 1060 nm in the bandwidth emitted from the ytterbium optical fiber laser 300 into a medium, for instance, optical fiber. Also, in order to enhance the efficiency of the Stokes transition, a portion irradiated from the wavelength division combiner out of the power backward irradiated from the medium is reflected using the mirror 340 having the reflectivity of 100%. Further, it is possible to obtain a considerable amount of power in a desired Stokes wavelength by optionally injecting a light source into the Stokes transition wavelength utilizing the laser diode pump light sources 310 and 320, and the pump combiner from an outside.

FIG. 3B is a graph showing a result measuring a cascaded Raman Stokes wavelength transition of the wideband multi-channel laser according to the pump structure of FIG. 3A at the point "A" of FIG. 3A, which shows the power that propagate backward. In FIG. 3B, both of the result (dotted line) with the mirror and the result (solid line) without the mirror are illustrated. Referring to the graph of FIG. 3B, it is possible to observe an apparent difference in the efficiency. In other words, without the mirror, Stokes transition to the frequency band of 1400 nm almost does not occur, and there is little amplification in the frequency band of 1500 nm. On the contrary, with the mirror, the Stokes transition occurs up to the frequency band of 1500 nm, and it is possible to observe that multi-channel is created by the aforementioned procedure.

FIG. 4 is a graph showing output spectra of a wideband multi-channel laser in accordance with one preferred embodiment of the present invention. Referring to FIG. 4, it is understood that a lasing multi-channels of at least 14 times compared with the conventionally known BEFL can be obtained, at much more enhanced gain flatness without the need of performing a special optimization procedure.

FIG. 5 is a schematic view of a multi-channel creation mechanism that is necessary for realizing a multi-channel light source of the present invention. Referring to FIG. 5, it was known in the past that several Stokes wavelengths could be obtained by this manner if the gain does not exist. However, if Raman gain is provided in the medium, respective Stokes powers of individual channels exceed a Brillouin critical power of the medium, so that continuous multi-channel can be obtained. Here, if there does not exist the Rayleigh scattering or feedback from the outside, the continuous multi-channel will be created every two multiple wavelength of the Brillouin transition when viewed from the end of the optical fiber, but if there exists a strong feedback, since there exists a power that proceeds in bidirections with a considerable intensity at the respective wavelengths, the lasing can be performed at all the respective transition frequencies.

FIG. 6A is a schematic view of a multi-channel laser light source in accordance with another embodiment of the present invention. Referring to FIG. 6A, it is shown that mirrors 160 and 160′ having a partial reflection function are further installed at the input and output terminals of the medium. Thus, it is possible to enhance the lasing efficiency through a further amplification of the light in the medium by amplifying means 150.

FIG. 6B is a schematic view of a ring-shaped multi-channel laser light source in accordance with still another embodiment of the present invention. The ring-shaped multi-channel laser is constituted to basically connect the input terminal and the output terminal of the medium to each other and to inject the Brillouin pump through a combiner.

In FIGs. 6A and 6B, since the elements having the identical reference numerals to those of FIG. 2 represent the same elements as those of FIG. 2, their description is intentionally omitted.

FIG. 7 is a schematic view of a light source to which a means for extracting a wavelength with a wider spacing is added. Referring to FIG. 7, a filter 180 having the periodicity is connected to the output terminal, thereby capable of extracting desired wavelength spacing. Also, from the desired wavelength spacing, it is possible to create a desired frequency, especially a beat wavelength of THz range. Instead of the filter 180, a Fabry-Perot interferometer can be implemented, to extract desired wavelength spacing. Meanwhile, the wavelength spacing can be controlled by varying the concentration of a additive gain substance in the medium without adding the extracting means.

Industrial Applicability

According to the embodiments of the present invention, a multi-channel laser light source with high-power and wideband, and operating in an arbitrary wavelength band can be realized. In other words, by effectively using stimulated Brillouin, stimulated Raman and Rayleigh scattering within an optical fiber, it becomes possible to create a multi-channel light having a precise wavelength spacing at a wavelength band corresponding to the Raman gain range. As a consequence of the embodiments, creation of a multi-channel having precise wavelength spacings of 700 or so was observed. Accordingly, by extending the Raman gain range in the same manner, creation of many channels is anticipated. The multi-channel laser light source can be applied to the creation of the THz beat frequency or the creation of the frequency standard.

Claims

1. A multi-channel light source comprising:

a medium having a gain by a non-linear Brillouin scattering effect and a pumping;

a pumping means optically coupled to the medium, for irradiating a pumped light so as to generate the pumping effect;

an external light source for introducing its output light thereof so as to generate a multi-wavelength light signal from the medium; and

an output means connected to the medium so as to receive the multi-wavelength light signal generated from the medium.

2. The multi-channel light source as claimed in claim 1, wherein the pumping means is a pump light source with a single wavelength.

3. The multi-channel light source as claimed in claim 1, wherein the pumping means is a pump light source having a plurality of wavelengths.

4. The multi-channel light source as claimed in claim 1, wherein the medium is the medium having a distributed gain.

5. The multi-channel light source as claimed in claim 1, wherein the medium is an optical fiber into which gain material is doped.

6. The multi-channel light source as claimed in claim 5, wherein the optical fiber is a dispersion compensating optical fiber.

7. The multi-channel light source as claimed in claim 1, wherein the pumping means is a Raman pump light source, has a structure using Raman Stokes transition from the light source having a high power, with enhanced efficiency thereof by including a reflection using a combiner and a mirror, or injecting power at a Stokes wavelength from an outside.

8. The multi-channel light source as claimed in claim 1, further comprising a wavelength spacing selection means at a next stage of the output means.

9. The multi-channel light source as claimed in claim 8, wherein the wavelength spacing selection means is a filter having periodicity or a Fabry-Perot filter.

10. The multi-channel light source as claimed in claim 1, further comprising partial transmission mirrors installed at both sides of the medium.

11. The multi-channel light source as claimed in claim 1, further comprising a ring-shaped optical path connecting an input terminal and an output terminal of the medium to each other.

FIG.1
(Prior Art)

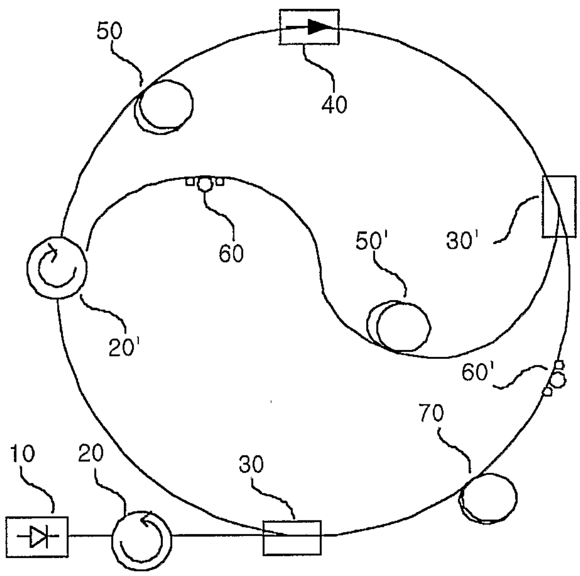


FIG.2

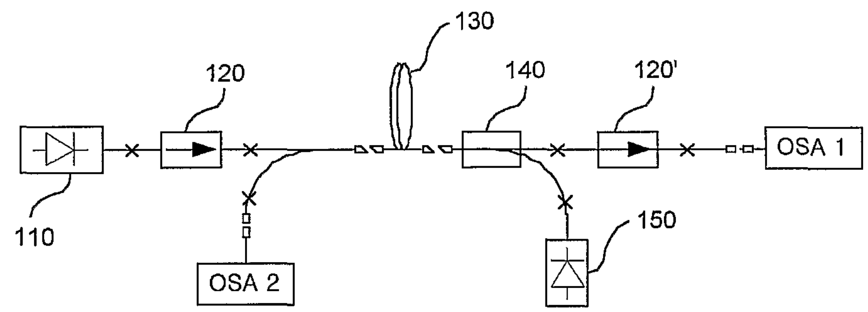

130
120
140
120'
OSA 1
110
OSA 2
150

FIG.3A

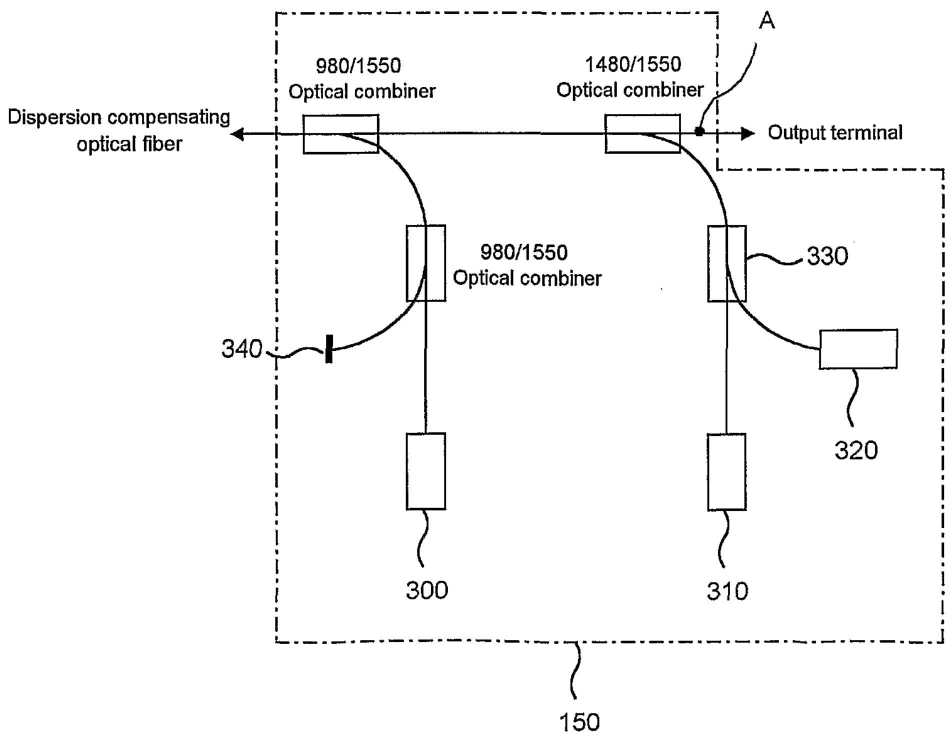

A
980/1550
Optical combiner
1480/1550
Optical combiner
Dispersion compensating
optical fiber
Output terminal
980/1550
Optical combiner
330
340
320
300
310
150

FIG.3B

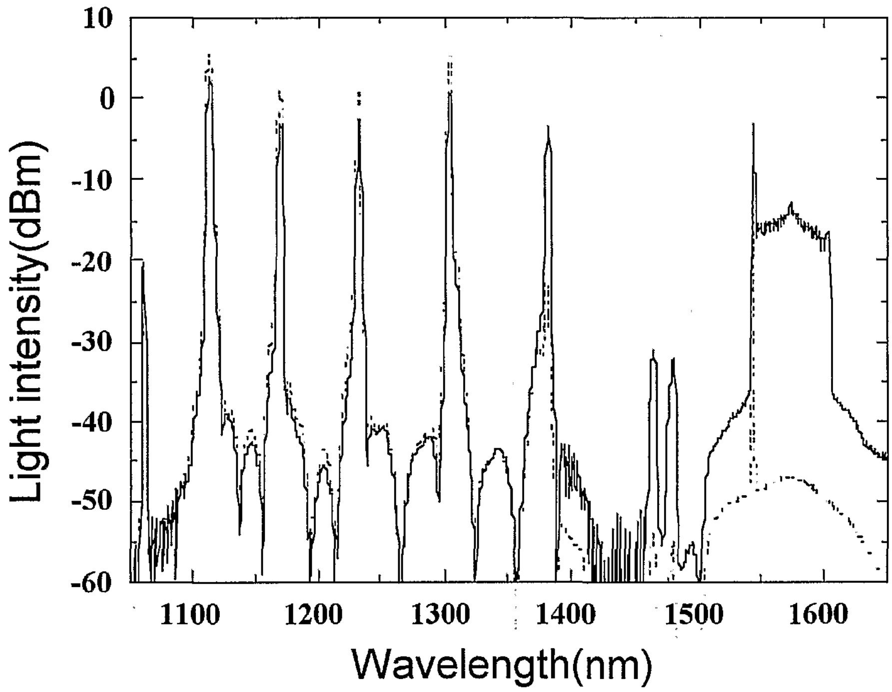

10
0
-10
-20
-30
-40
-50
-60
Light intensity(dBm)
1100
1200
1300
1400
1500
1600
Wavelength(nm)

FIG.4

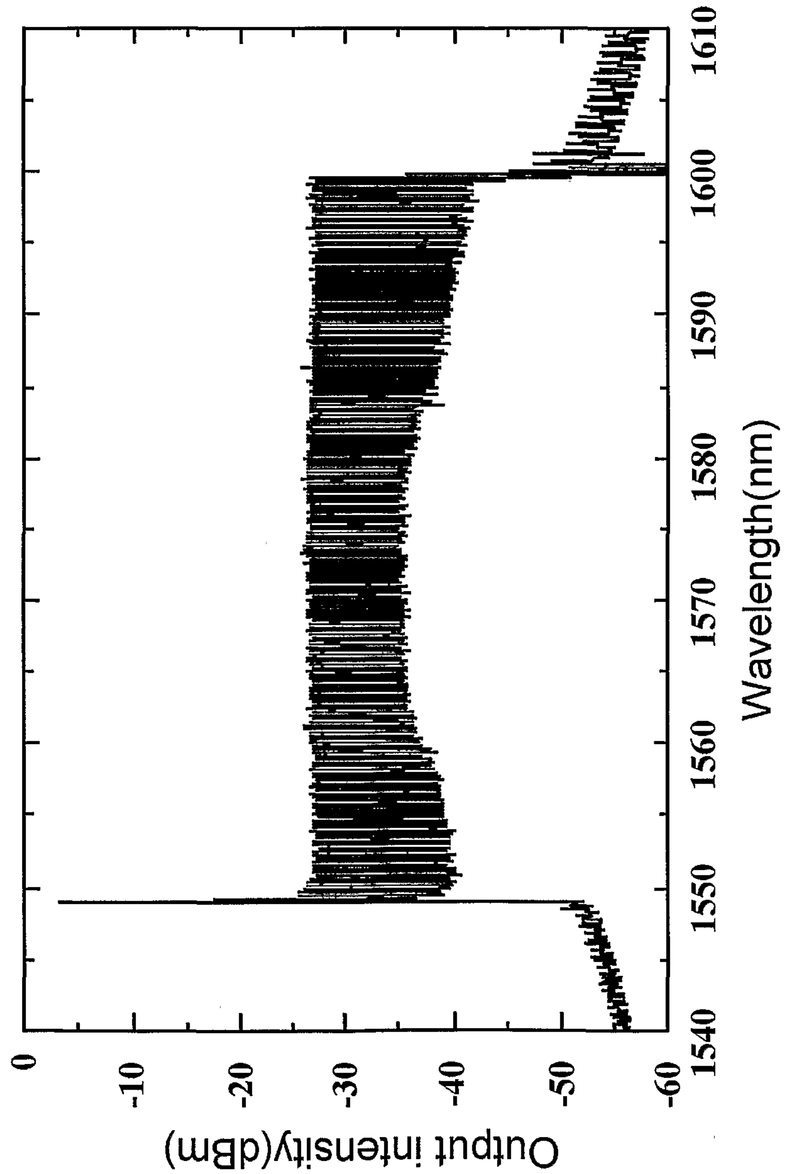

Output intensity(dBm)
0
-10
-20
-30
-40
-50
-60
Wavelength(nm)
1540
1550
1560
1570
1580
1590
1600
1610

FIG.5

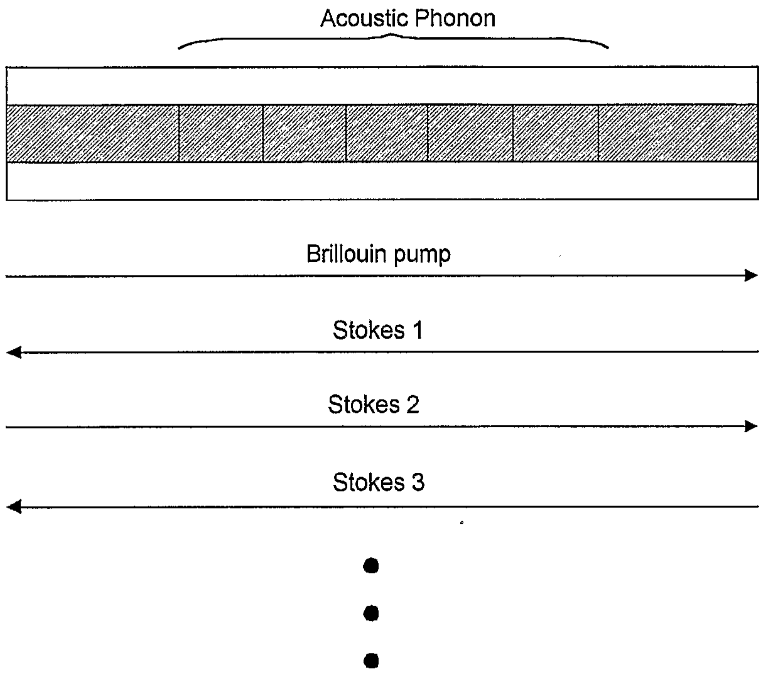

Acoustic Phonon
Brillouin pump
Stokes 1
Stokes 2
Stokes 3

FIG.6A

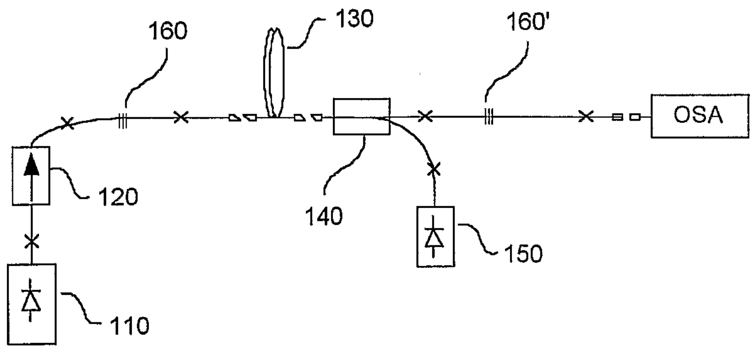

160
130
160'
OSA
120
140
150
110

FIG.6B

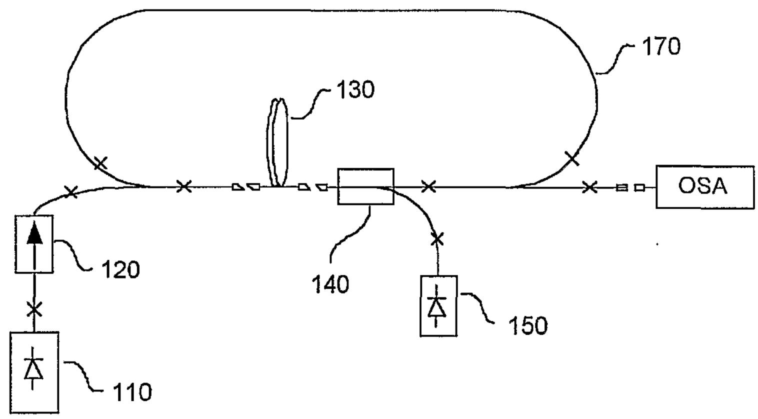
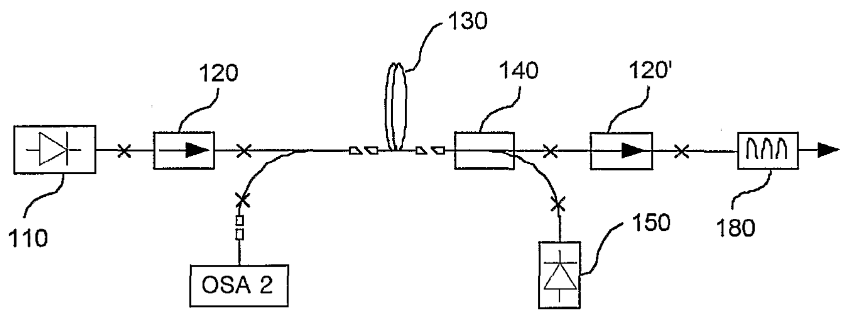


FIG.7



INTERNATIONAL SEARCH REPORT

International application No. PCT/KR02/00469

A. CLASSIFICATION OF SUBJECT MATTER

IPC7 G02B 6/293, G02F 1/35

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)

IPC7 (the entire class)

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

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

KIPASS "brillouin* ", "scatter* ", "pump* ", "light source* "

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,598,289 A (FUJITSU Ltd.) 28, JANUARY, 1997 See the whole document	1 - 11
A	US 6,052,393 A (UNIV MICHIGAN) 18, APRIL, 2000 See the whole document	1 - 11
A	WO00/05622 (FURUKAWA ELECTRIC Co.) 03, FEBRUARY, 2000 See the whole document	1 - 11

☐ 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 relevence

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"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 relevence; 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 relevence; 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
18 JUNE 2002 (18.06.2002)	19 JUNE 2002 (19.06.2002)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR02/00469

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5,598,289 A	28-01-1997	NONE	
US 6,052,393 A	18-04-2000	NONE	
WO00/05622	03-02-2000	US 6,292,288 A	18-09-2001