



(51) International Patent Classification:

H01S 5/0683 (2006.01) H01S 5/0625 (2006.01)
H01S 5/50 (2006.01) H01S 5/026 (2006.01)
H04B 10/291 (2013.01) H04B 10/294 (2013.01)
H01S 5/00 (2006.01)

(21) International Application Number:

PCT/IB2017/000603

(22) International Filing Date:

21 March 2017 (21.03.2017)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

201610183621.7 28 March 2016 (28.03.2016) CN

(71) Applicant: ALCATEL LUCENT [FR/FR]; 148/152 route de la Reine, 92100 Boulogne-Billancourt (FR).

(72) Inventors: SUN, Xiao; 388# Ningqiao Road, Pudong Jinqiao, Shanghai 201206 (CN). GAO, Zhensen; 388# Ningqiao Road, Pudong Jinqiao, Shanghai 201206 (CN).

(74) Agent: SARUP, David Alexander; Alcatel-Lucent Telecom Ltd, Christchurch Way, Greenwich, London Greater London SE10 0AG (GB).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

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

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

Published:

- with international search report (Art. 21(3))
- 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: SEMICONDUCTOR OPTICAL AMPLIFIER DEVICE AND METHOD OF OPERATING IT

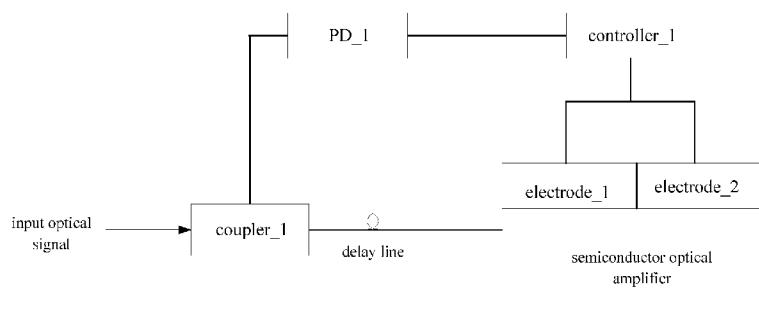


Fig. 4

(57) **Abstract:** An objective of the present invention is to provide a semiconductor optical amplifier (SOA) device, and a method of operating the SOA device. semiconductor optical amplifier (SOA) device, comprising: a semiconductor optical amplifier having a semiconductor substrate with an optical amplifier waveguide therein and a sequence of drive electrodes being located over a surface of aforesaid semiconductor substrate, aforesaid sequence extending along a light propagation direction in aforesaid optical amplifier waveguide; a light detector connected to measure a power of signal light input to aforesaid semiconductor optical amplifier; an electronic controller configured to inject currents into said sequence of drive electrodes based on aforesaid power measurement by the light detector. Compared with the prior art of an SOA device generally having one driving electrode, the present invention has the following advantages: by adjusting the magnitudes of currents injected into respective driving electrodes of the semiconductor optical amplifier, the solution of the present invention can increase the linear amplification region, thereby performing error-free signal amplification within a greater reception power range, which further avoids distortion of signal transmission.



SEMICONDUCTOR OPTICAL AMPLIFIER DEVICE AND METHOD OF OPERATING IT

FIELD OF THE INVENTION

- 5 [1] The present invention relates to optical communication technologies, and more particularly to a semiconductor optical amplifier (SOA) device and a method of operating it.

BACKGROUND OF THE INVENTION

- 10 [2] Optical amplifiers are widely applied in current PONs (Passive Optical Networks) and FTTHs (Fiber-to-the-Homes) to extend reach and power split ratios. Signal amplification is needed prior to downlink signal transmission due to the modest output power of a tunable laser source and insertion loss introduced by external modulation. On the other hand, due to long-distance passive transmission and high split ratio, an uplink signal receiving power can be very low. On this occasion, signal pre-amplification is required to achieve error-free reception in a central office (CO). Besides, some research institutions and network vendors are discussing and proposing extending the reach and power split ratio of optical access networks to 100km and 1:256 or even 1:1024, respectively. System loss budgets will increase dramatically to realize the long-distance optical network transmission.

- 15 [3] Among all optical amplifiers, a semiconductor optical amplifier (SOA) will become a most competitive candidate due to its polarization insensitive gain, lower cost, lower noise coefficient, and higher gain, thereby increasing the number of clients and the reach served by the same CO traffic. Besides, the ultra-broad wavelength window (from 1280nm to 1650nm) of SOAs makes them more attractive compared with conventional erbium doped fiber amplifiers (EDFAs). However, performance requirements on SOAs are challenging, especially in the uplink transmission direction. Discrepancies among geographical positions of respective users and the multi-stage asymmetrical network architecture of splitters lead to different path losses for the users, ending up with strong signal power variations at the SOA input. This requires the SOAs to have a high input power dynamics range (IPDR) or a wide linear region to achieve error free amplification. The IPDR is defined as allowable input maximum signal power range to guarantee no signal distortion during the SOA amplification process. Fig. 1 is a structural diagram of an SOA according to the prior art. Because the linear region of the SOA based on the prior art is limited, its IPDR is usually very limited.

- 20 [4] A linear optical amplifier (LOA) is employed in an existing approach of increasing the SOA. Both LOA and SOA are semiconductor devices with advantages such as small size, convenience to integrate, and an ultra-wide gain spectrum. The LOA may be applied to a wavelength division multiplexing (WDM) network due to its great advantages such as ultra-linear amplification gain, high saturation output, low cross talk, low noise, and wideband gain clamping, etc., and particularly applied to simultaneously amplification of multi-channel signals.

- 25 [5] Compared with the SOA, a significant difference of the LOA is that a vertical-cavity surface-emitting laser (VCSEL) has to be integrated inside the LOA to provide a constant amplification gain and clamp gain competition within the laser cavity. Because the light output direction of the VCSEL is perpendicular to the light propagation path within the SOA, the optical field of the VCSEL is orthogonal to and decoupled with that of the SOA. Consequently, it is not needed to filter the light source from the VCSEL from the SOA output end.

- [6] However, the gain clamping mechanism adopted by the LOA causes the linear gain of the LOA significantly lower than the SOA. Further increase of the linear region of the LOA will reduce more linear gain as a sacrifice. Besides, it is rather difficult to manufacture a high performance VCSEL in C+L band, such that it remains a technical bottleneck regarding how to enhance power stability of the LOA. Compared with the SOA, manufacturing of the LOA has a higher cost and a more complex manufacturing process.

SUMMARY OF THE INVENTION

- [7] An objective of the present invention is to provide a semiconductor optical amplifier (SOA) device, and a method of operating the SOA device.
- [8] According to a first aspect of the present invention, there is provided a semiconductor optical amplifier (SOA) device, comprising:
- [9] a light detector connected to measure a power of signal light input to aforesaid semiconductor optical amplifier;
- [10] an electronic controller configured to inject currents into said sequence of drive electrodes based on aforesaid power measurement by the light detector;
- [11] a semiconductor optical amplifier having an upper-layer semiconductor substrate and a lower-layer semiconductor substrate, a semiconductor waveguide layer being provided between the upper-layer semiconductor substrate and the lower-layer semiconductor substrate, and a plurality of driving electrodes being provided on a surface of the upper-layer semiconductor substrate, the plurality of driving electrodes extending along a light propagation direction in the waveguide layer of the optical amplifier.
- [12] According to one aspect of the present invention, there is also provided a method of operating an SOA device, the method comprising steps of:
- [13] a. monitoring a power of an optical signal input to the SOA device, aforesaid SOA device having a sequence of semiconductor optical amplifying regions and drive electrode sets, each optical amplifying region being connected to receive a drive current from a corresponding one of the drive electrode sets, and
- [14] b. adjusting currents injected by the drive electrode sets into the semiconductor optical amplifying regions based on aforesaid monitored power of the input optical signal.
- [15] Compared with the prior art of an SOA device generally having one driving electrode, the present invention has the following advantages: by adjusting the magnitudes of currents injected into respective driving electrodes of the semiconductor optical amplifier, the solution of the present invention can increase the linear amplification region, thereby performing error-free signal amplification within a greater reception power range, which further avoids distortion of signal transmission.

BRIEF DESCRIPTION OF THE ACCOMPANYING DRAWINGS

- [16] Other features, objectives and advantages of the present invention will become more apparent through reading the detailed depictions of the non-limiting embodiments with reference to the drawings below:
- [17] Fig. 1 is a structural diagram of an SOA based on the prior art;
- [18] Fig. 2 is a structural diagram of a semiconductor optical amplifier (SOA) according to the present invention;

[19] Fig. 3 is a structural diagram of a semiconductor optical amplifier according to an embodiment of the present invention;

[20] Fig. 4 is a structural diagram of an SOA device according to the present invention;

5 [21] Fig. 5 is a schematic diagram of a method of operating the SOA device according to the present invention;

[22] Fig. 6 is a schematic diagram of an exemplary passive optical network according to the present invention;

[23] In the drawings, same or similar reference numerals represent same or similar components.

10 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

[24] Hereinafter, the present invention will be described in further detail with reference to the accompanying drawings.

15 [25] Fig. 2 is a structural diagram of a semiconductor optical amplifier (SOA) according to the present invention. The SOA device according to the present invention comprises a light detector 1, a electronic controller 2, and a semiconductor optical amplifier 3.

[26] Particularly, the light detector 1 is configured to measure power of an optical signal inputted to the semiconductor optical amplifier;

[27] Preferably, the light detector 1 comprises a photodiode or a phototransistor connected to receive part of aforesaid signal light.

20 [28] Particularly, the electronic controller 2 is configured to inject multi-path currents into respective drive electrodes based on the power measured by the light detector.

[29] Specifically, the electronic controller 2 may split current from the light detector 1 into multiple paths of currents and then inject the multi-path currents into respective drive modes. Moreover, the electronic controller 2 may adjust the magnitude of each injected current into the
25 drive electrodes.

[30] Particularly, those skilled in the art may determine one or more elements that are needed to implement the control means according to actual conditions and needs, which will not be detailed here.

30 [31] Particularly, the semiconductor optical amplifier 3 has an upper-layer semiconductor substrate and a lower-layer semiconductor substrate, a semiconductor waveguide layer being provided between the upper-layer semiconductor substrate and the lower-layer semiconductor substrate, and a plurality of driving electrodes being provided on a surface of the upper-layer semiconductor substrate, the plurality of drive electrodes extending along a light propagation direction in the waveguide layer of the optical amplifier.

35 [32] Preferably, the semiconductor optical amplifier 3 also has an electrical insulating region being located over aforesaid surface and being partially located between neighboring edges of aforesaid drive electrodes..

[33] Particularly, the insulated region may be formed by various kinds of electric insulation materials.

40 [34] Preferably, under and between aforesaid drive electrodes, aforesaid optical amplifier waveguide does not have an optical interface transverse to aforesaid light propagation direction therein.

[35] For example, referring to the semiconductor optical amplifier according to an embodiment of the present invention as shown in Fig. 3, a substrate of the semiconductor optical amplifier

comprises an upper coverage layer and a lower coverage layer, the optical amplifier waveguide layer being disposed between the upper coverage layer and the lower coverage layer; and two electrodes are provided on a surface of the upper coverage layer of the semiconductor optical amplifier, between the two electrodes being provided an isolating layer of a silicon dioxide material to form an insulated region.

[36] It needs to be noted that the semiconductor optical amplifier 3 according to the present invention may have more than two drive electrodes, not limited to the two drive electrodes shown in Fig. 3.

[37] Preferably, the SOA device according to the present invention further comprises an optical splitter and an optical delay device.

[38] Particularly, the optical splitter connected to transmit a portion of aforesaid signal light to aforesaid light detector and to transmit a portion of aforesaid signal light to aforesaid semiconductor optical amplifier.

[39] Particularly, the optical splitter may be implemented by a device that may split the input optical signal such as a light coupler or a light splitter.

[40] Particularly, the optical delay device is placed between said optical splitter and an optical input of said semiconductor optical amplifier.

[41] Preferably, the optical delay device includes various kinds of devices that may delay the correction signal for a period of time, e.g., a segment of optical fiber delay line of an appropriate length, or an optical device that may delay a signal.

[42] For example, referring to an SOA device according to an embodiment of the present invention as shown in Fig. 4, the SOA device comprises a semiconductor optical amplifier amp_1, a coupler coupler_1, a photoelectric diode PD_1, and a controller con_1; moreover, a segment of delay line is provided between the coupler_1 and the semiconductor optical amplifier amp_1.

Particularly, on a surface of the semiconductor substrate of the semiconductor optical amplifier amp_1 are provided two driving electrodes electrode_1 and electrode_2, lengths of the two drive electrodes along a light propagation direction are equal.

[43] Particularly, the input optical signal is transmitted to the optical amplifier amp_1 via the coupler coupler_1 and the delay line, and is amplified via the optical amplifier amp_1 and then output.

[44] Particularly, the light coupler coupler_1 transmits part of the input optical signal to the photoelectric diode PD_1. The optical coupler coupler_1 transmits remaining part of the input optical signal to the semiconductor amplifier amp_1.

[45] Particularly, the photoelectric diode PD_1 receives part of the optical signal from the coupler_1 and measures it.

[46] Particularly, controller_1 receives the signal from the photoelectric diode PD_1, splits the signal into two paths according to a power strength of the received signal, and injects the two paths of signal into the drive electrodes electrode_1 and electrode_2; moreover, the controller_1 may adjust the magnitudes of currents injected to the drive electrodes electrode_1 and electrode_2 based on the power measured by the photoelectric diode PD_1.

[47] Compared with the prior art of an SOA device generally having one driving electrode, by adjusting the magnitudes of currents injected into respective driving electrodes of the semiconductor optical amplifier, the solution of the present invention can increase the linear amplification region, thereby performing error-free signal amplification within a greater reception

power range, which further avoids distortion of signal transmission.

[48] Fig. 5 is a schematic diagram of a method of operating the SOA device according to the present invention. The method according to the present invention comprises step S1 and step S2.

[49] In step S1, a light detector 1 monitoring a power of an optical signal input to the SOA device, aforesaid SOA device having a sequence of semiconductor optical amplifying regions and drive electrode sets, each optical amplifying region being connected to receive a drive current from a corresponding one of the drive electrode sets.

[50] Particularly, each amplifying region receives the driving current from its respective drive electrode to implement different amplification gains, and each amplification region is connected to ensure smooth transmission of the optical signal.

[51] In step S2, the electronic controller 2 adjusts currents injected by the drive electrode sets into the semiconductor optical amplifying regions based on aforesaid monitored power of the input optical signal.

[52] Specifically, the electronic controller 2 may adjust magnitudes of current injected into the plurality of semiconductor optical amplification regions through the plurality of drive electrodes based on the detected power of the input optical signal as well as a correspondence relationship between a predetermined optical signal power and a magnitude of current injected through respective drive electrode.

[53] Preferably, electronic controller 3 adjusts one or more injected current so that a ratio of two of aforesaid injected currents has a first value in response to aforesaid monitored power being less than a predefined threshold; electronic controller 3 adjusts the one or more injected currents so that aforesaid ratio of aforesaid two of aforesaid injected currents has a different second value in response to aforesaid monitored power being more than aforesaid predefined threshold.

[54] For example, referring to the SOA device as shown in Fig. 4, a rule for operating the SOA device indicates that if a power value of the input optical signal is smaller than a threshold P_{th} , adjusting the magnitudes of currents injected to the electrode_1 and electrode_2, such that a ratio between current densities corresponding to the electrode_1 and electrode_2 is 1:1; otherwise, adjusting the magnitudes of currents injected to the electrode_1 and electrode_2, such that a ratio between current densities corresponding to the electrode_1 and electrode_2 is 0.67:1.

[55] Because the sizes of the two driving electrodes electrode_1 and electrode_2 are equal, the ratio between currents I_1 and I_2 respectively injected to the electrode_1 and electrode_2 is equal to a ratio between densities of the currents injected to the electrode_1 and electrode_2.

[56] Based on this rule, if the power value of the input optical signal detected by PD_1 is smaller than a threshold P_{th} , the controller controller_1 adjusts magnitudes of the injected currents I_1 and I_2 , such that $I_1:I_2 = 1:1$. If the power value of the input optical signal detected by PD_1 is greater than or equal to the threshold P_{th} , the controller controller_1 adjusts magnitudes of the injected currents I_1 and I_2 , such that $I_1:I_2 = 0.67:1$.

[57] Compared with the prior art of an SOA device generally having one driving electrode, by adjusting the magnitudes of currents injected into respective driving electrodes of the semiconductor optical amplifier, the method of the present invention can increase the linear amplification region, thereby performing error-free signal amplification within a greater reception power range, which further avoids distortion of signal transmission.

[58] Fig. 6 is a schematic diagram of an exemplary passive optical network according to the present invention.

[59] Referring to Fig. 6, the passive optical network comprises a relay node, N optical network units (ONU_1 to ONU_2), two splitters splitter_1 and splitter_2, wherein splitter_1 is 1 in 4 outs, while splitter_2 is 1 in 16 outs. Particularly, the relay node comprises an SOA device shown in Fig. 4.

5 [60] Particularly, the ONU_1 is connected to the splitter splitter_1, the ONU_2 – ONU_N are connected to splitter_2 and further connected to splitter_1 via the splitter_2, wherein ONU_1 is 20km away from splitter_1, ONU_2 is 20km away from splitter_1, while the distance between splitter_2 and splitter_1 is less than 100m.

10 [61] Particularly, when the ONU_1 and ONU_2 transmit data to the relay node, supposing the output power of laser emitters of all optical network elements is 0 dBm, the respective total power losses of ONU_1 and ONU_2 and the reception power arriving at the SOA device input end are shown in Table 1 below:

Table 1

	ONU_1	ONU_2
Total power loss	10 dB	22dB
Reception power	-10dB	-22dB

15 Based on table 1 above, the total IPDR of ONU_1 and ONU_2 is 12dB. When amplifying the signal from ONU_1, the controller in the SOA device adjusts the magnitudes of injected currents I_1 and I_2 , such that $I_1:I_2 = 0.67:1$. When amplifying the signal from ONU_2, the controller adjusts the magnitudes of injected currents I_1 and I_2 , such that $I_1:I_2 = 1:1$, thereby guaranteeing that the signals from ONU_1 and ONU_2 are all amplified in the linear region. However, if the signal
 20 from the ONU_1 is amplified using a common SOA device having one driving electrode, signal distortion possibly occurs, because for the SOA with only one driving electrode, the allowable maximum input optical power is -11dB.

[62] The SOA device according to the present invention may be disposed in a plurality of network nodes, e.g., serving as a downlink signal power enhancing apparatus or an uplink signal
 25 pre-amplifying apparatus in CO, or serving as a reach extending apparatus in a remote node (RN), etc. Those skilled in the art may deploy the SOA device of the present invention into an appropriate network node.

[63] To those skilled in the art, it is apparent that the present invention is not limited to details of the illustrative embodiments, and the present invention can be implemented in other specific form
 30 without departing from spirits or basic features of the present invention. Therefore, in any way, the embodiments should be regarded as illustrative, not limitative; the scope of the present invention is limited by the appended claims, not the depictive limitations above. Therefore, meanings falling in equivalent elements of the claims and all changes within the scope should be covered by the present invention. No reference numerals in the claims should be regarded as limiting the involved
 35 claims. In addition, the word “comprise” or “include” does not exclude other units or steps, and singularity does not exclude plurality. A plurality of units or devices stated in system claims may also be implemented by one unit or module through software or hardware. Words like first and second are used to indicate names, instead of any specific sequences.

Claims

1. An semiconductor optical amplifier (SOA) device, comprising:
a semiconductor optical amplifier having a semiconductor substrate with an optical amplifier waveguide therein and a sequence of drive electrodes being located over a surface of aforesaid semiconductor substrate, aforesaid sequence extending along a light propagation direction in aforesaid optical amplifier waveguide;
a light detector connected to measure a power of signal light input to aforesaid semiconductor optical amplifier;
an electronic controller configured to inject currents into said sequence of drive electrodes based on aforesaid power measurement by the light detector.
2. The SOA device according to claim 1, further comprising an electrical insulating region being located over aforesaid surface and being partially located between neighboring edges of aforesaid drive electrodes.
3. The SOA device according to claim 1 or 2, wherein under and between aforesaid drive electrodes, aforesaid optical amplifier waveguide does not have an optical interface transverse to aforesaid light propagation direction therein.
4. The SOA device according to any one of claims 1-3, wherein said light detector comprises a photodiode or a phototransistor connected to receive part of aforesaid signal light.
5. The SOA device according to any one of claims 1-4, further comprising:
an optical splitter connected to transmit a portion of aforesaid signal light to aforesaid light detector and to transmit a portion of aforesaid signal light to aforesaid semiconductor optical amplifier; and
an optical delay device placed between said optical splitter and an optical input of said semiconductor optical amplifier.
6. A method of operating an SOA device, the method comprising the following steps:
a monitoring a power of an optical signal input to the SOA device, aforesaid SOA device having a sequence of semiconductor optical amplifying regions and drive electrode sets, each optical amplifying region being connected to receive a drive current from a corresponding one of the drive electrode sets; and
b adjusting currents injected by the drive electrode sets into the semiconductor optical amplifying regions based on aforesaid monitored power of the input optical signal.
7. The method according to claim 6, wherein the step of adjusting the injected currents further comprises:
- adjusting the one or more injected current so that a ratio of two of aforesaid injected currents has a first value in response to aforesaid monitored power being less than a predefined threshold;
- adjusting the one or more injected currents so that aforesaid ratio of aforesaid two of aforesaid injected currents has a different second value in response to aforesaid monitored power being more than aforesaid predefined threshold.

Drawings

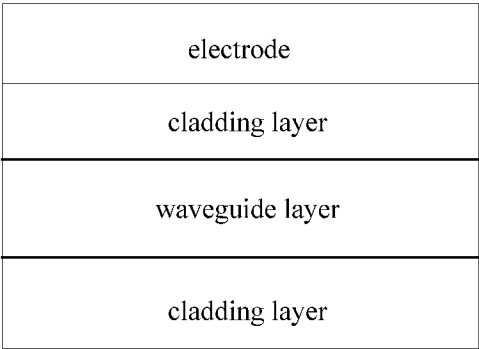


Fig. 1

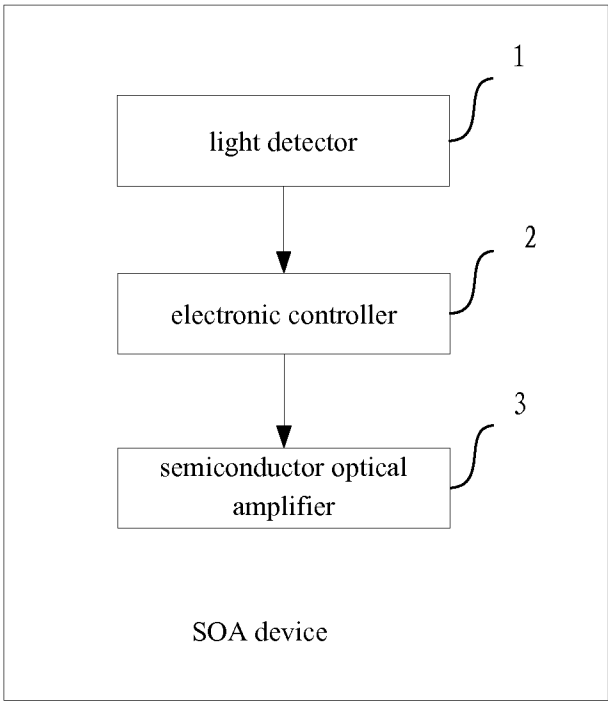


Fig. 2

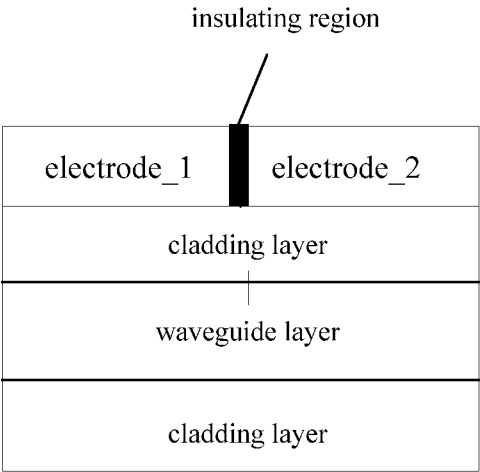


Fig. 3

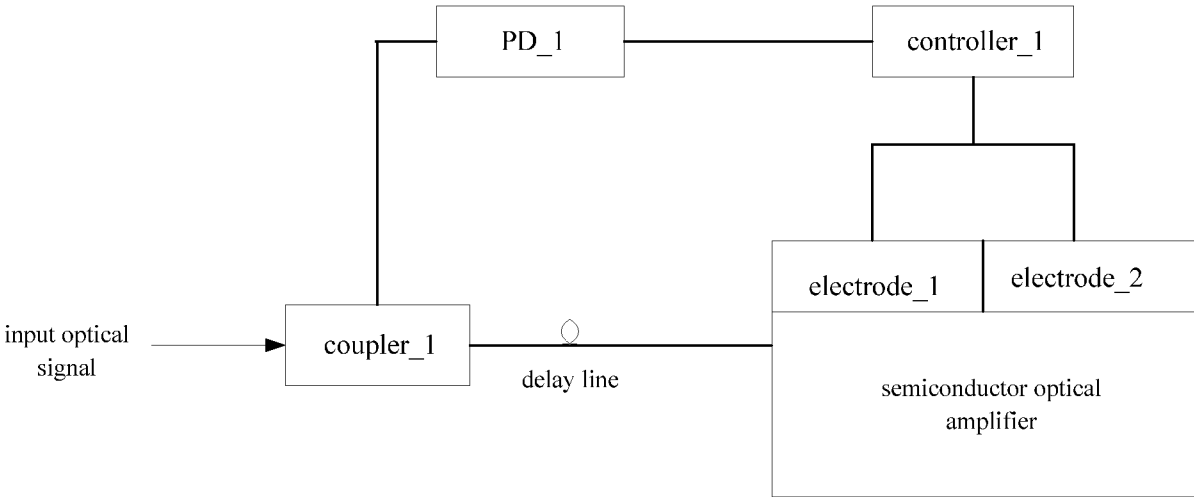


Fig. 4

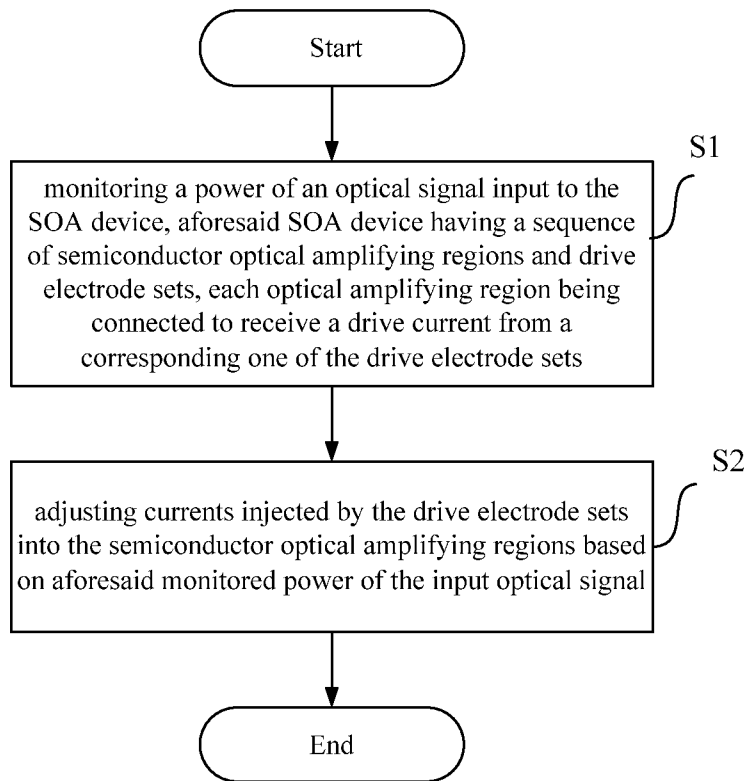


Fig. 5

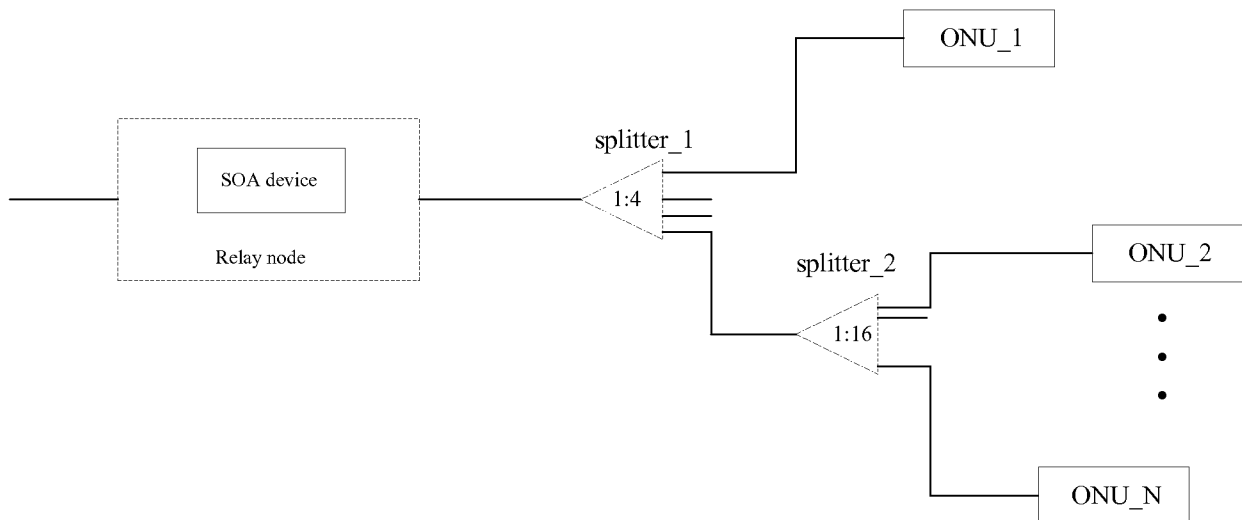


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2017/000603

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01S5/0683 H01S5/50 H04B10/291
ADD. H01S5/00 H01S5/0625 H01S5/026 H04B10/294

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 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, COMPENDEX, 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	US 2006/215255 A1 (AKIYAMA TOMOYUKI [JP]) 28 September 2006 (2006-09-28)	1-4,6,7
Y	paragraphs [0032] - [0151]; figures 1,2,5-7	5
Y	----- EP 1 079 481 A2 (LUCENT TECHNOLOGIES INC [US]) 28 February 2001 (2001-02-28)	5
	paragraphs [0012] - [0025], [0044]; figures 1-3	
A	----- US 6 731 427 B1 (WU YONGAN [US]) 4 May 2004 (2004-05-04)	1,6
	column 2, line 54 - column 8, line 44; figures 1-3,5-9	



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

26 July 2017

Date of mailing of the international search report

03/08/2017

Name and mailing address of the ISA/

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

Authorized officer

Laenen, Robert

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2017/000603

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006215255	A1	28-09-2006	EP 1705812 A1 27-09-2006
			JP 4632833 B2 23-02-2011
			JP 2006269926 A 05-10-2006
			US 2006215255 A1 28-09-2006
EP 1079481	A2	28-02-2001	CA 2315989 A1 25-02-2001
			CN 1286413 A 07-03-2001
			DE 60019212 D1 12-05-2005
			DE 60019212 T2 09-03-2006
			EP 1079481 A2 28-02-2001
			JP 2001111151 A 20-04-2001
			US 6366393 B1 02-04-2002
US 6731427	B1	04-05-2004	NONE