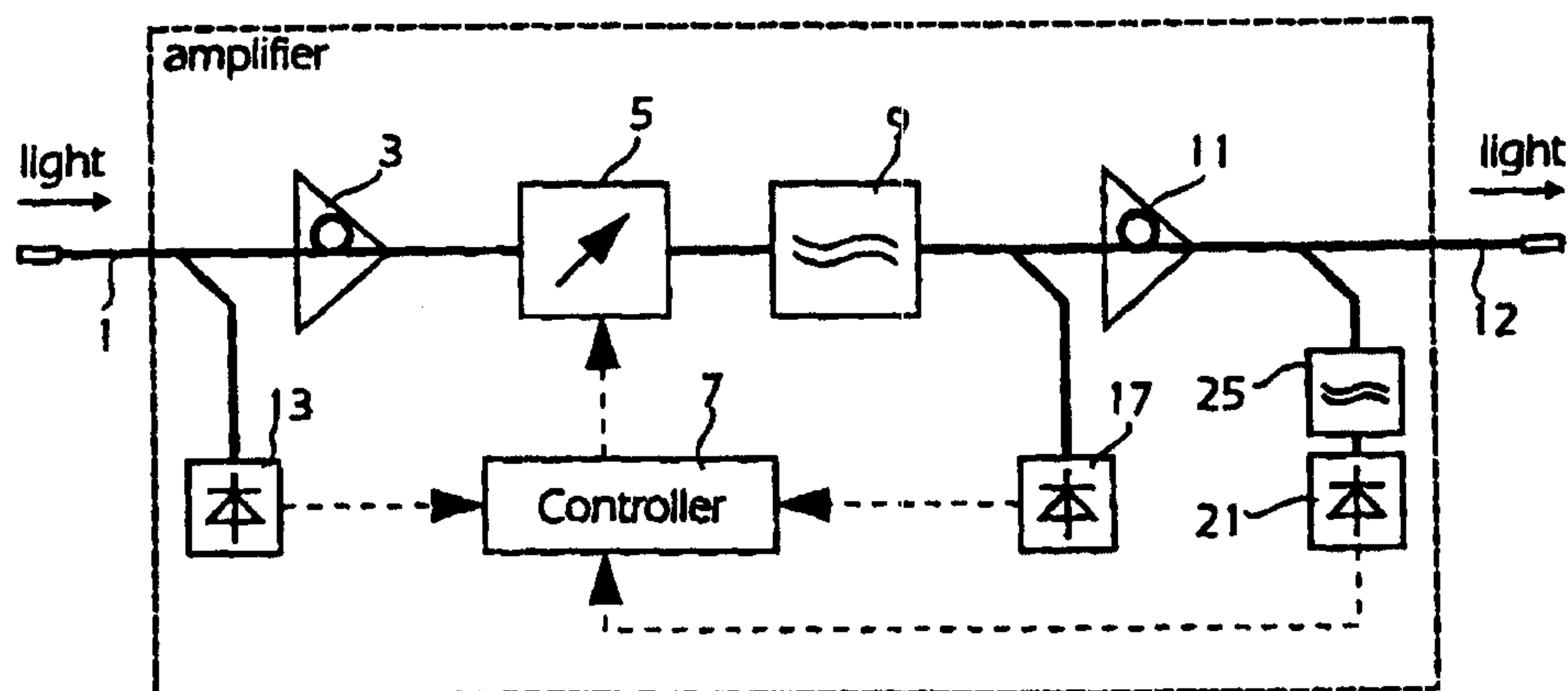


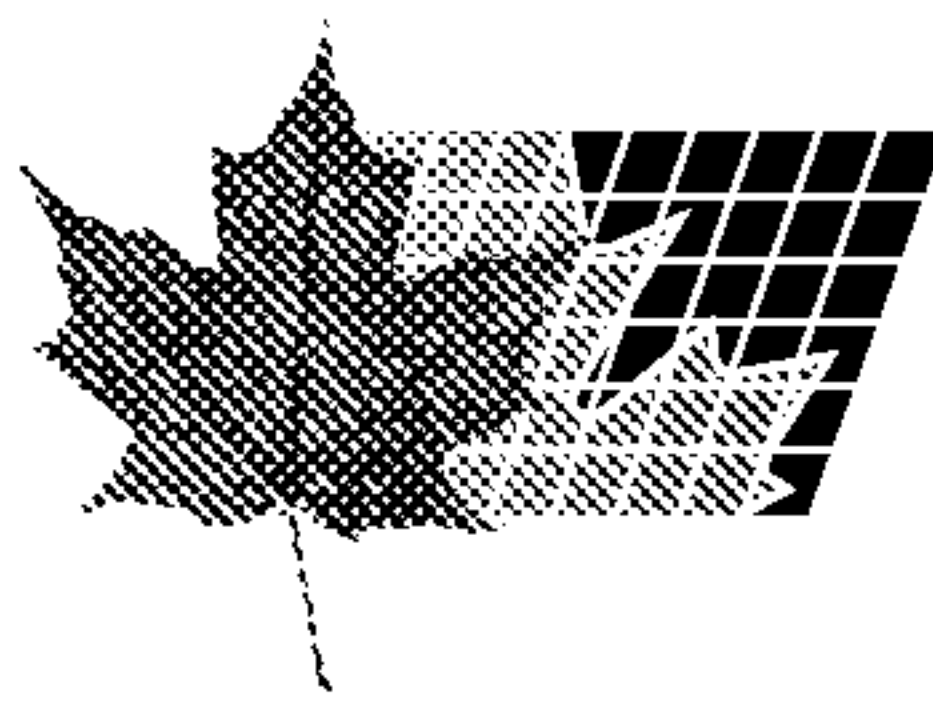


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(51) Int.Cl.⁶ H04B 10/17
(30) 1997/02/14 (9700533-4) SE
(54) **AMPLIFICATEUR A FIBRE OPTIQUE PRESENTANT UN GAIN VARIABLE**
(54) **OPTICAL FIBER AMPLIFIER HAVING VARIABLE GAIN**



(57) Amplificateur optique conçu pour des signaux lumineux WDM et comprenant un préamplificateur (3) et un amplificateur de puissance (11) du type amplificateur à fibre optique branchés en série et présentant des courbes de gain dépendantes de la longueur d'onde. Un atténuateur (5) pouvant être commandé est branché entre les amplificateurs (3 et 11) et est commandé par un dispositif de commande (7). L'entrée de signal dans le préamplificateur (3) possède

(57) An optical amplifier device intended for WDM light signals comprises a preamplifier (3) and a power amplifier (11) of the optical fiber amplifier type, which are connected in series and have gain curves dependent on the wavelength. A controllable attenuator (5) is connected between the amplifiers (3 and 11) and is controlled by a control device (7). The signal input to the preamplifier (3) has a low power and is amplified to provide an output signal where the signals of the input



(21) (A1) **2,280,962**
(86) 1998/02/13
(87) 1998/08/20

une puissance basse et est amplifiée de façon à produire un signal de sortie dans lequel les signaux des canaux d'entrée ont été amplifiés avec des gains différents. Le signal d'entrée de l'amplificateur de puissance (11) présente alors une puissance plus importante permettant d'obtenir une caractéristique de gain différente de celle du préamplificateur (3). L'adaptation de l'atténuation de l'atténuateur (5), dans le but d'apporter des variations dans le signal d'entrée, permet de régler la caractéristique de gain de l'amplificateur de puissance (11), de sorte que la sortie de signal de l'amplificateur possède une dépendance spectrale semblable à la dépendance spectrale originale obtenue sans variations. De même, on peut conserver la même dépendance spectrale quand la puissance de la lumière de pompage de l'amplificateur de puissance est modifiée et, par conséquent, quand le gain total de l'amplificateur est modifié, en adaptant l'atténuation de l'atténuateur (5), de manière à ne pas modifier le gain de l'amplificateur de puissance. Dans l'amplificateur, le bruit le plus bas possible depuis l'étage de préamplificateur est ajouté au signal d'entrée et la pleine puissance de sortie est toujours disponible depuis l'amplificateur de puissance. Si le signal d'entrée est, par exemple, amplifié, le SNR des signaux traversant l'amplificateur est, de ce fait, amélioré. Ceci améliore la capacité d'un réseau optique mettant en application cet amplificateur.

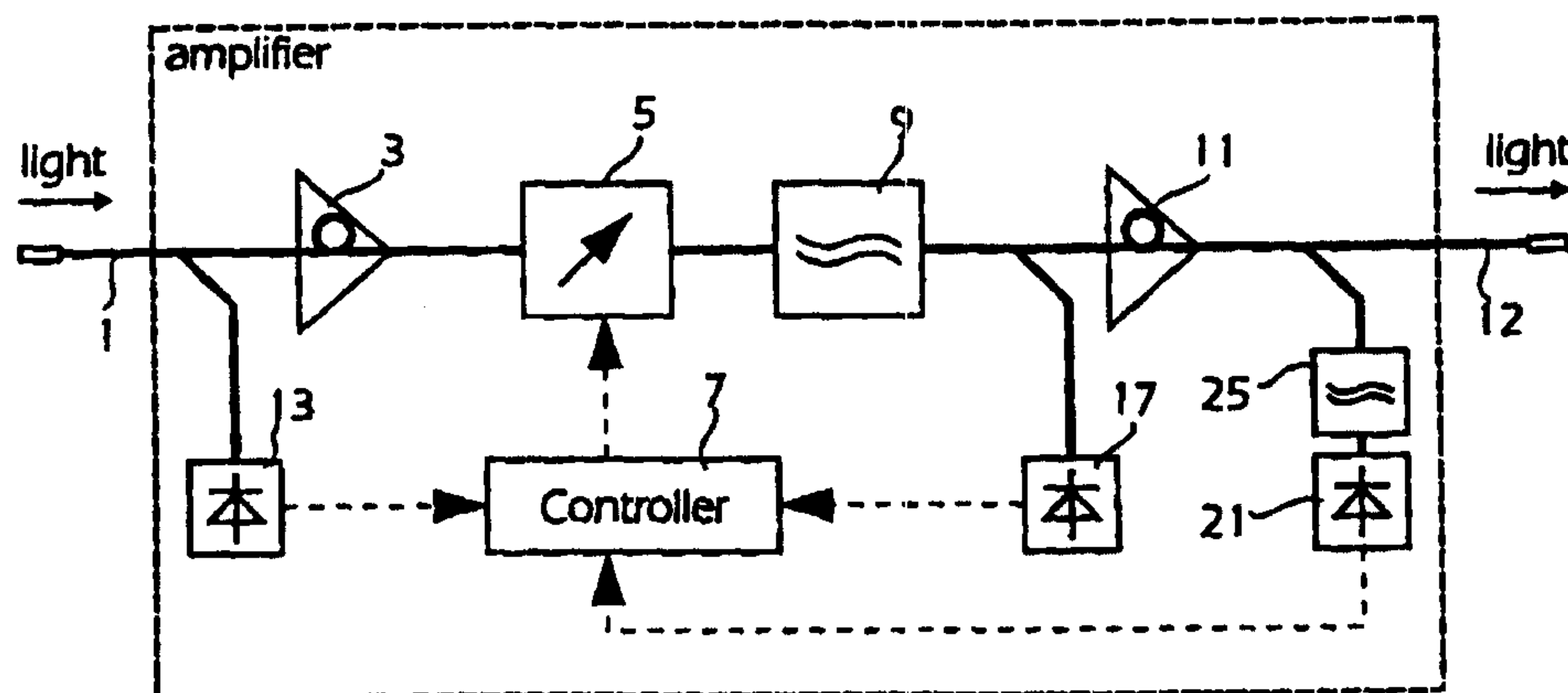
channels have been amplified with different gains. The input signal of the power amplifier (11) then has a larger power resulting in a gain characteristic different from that of the preamplifier (3). By adapting the attenuation of the attenuator (5) for variations in the input signal the gain characteristic of the power amplifier (11) can be set so that the signal output from the amplifier device has a spectral dependence that is the same as the original spectral dependence obtained without variations. Also, the same spectral dependence can be maintained when the pump light power of the power amplifier is changed and then the total amplifier gain is changed, by adapting the attenuation of the attenuator (5) so that the gain of the power amplifier is not changed. In the amplifier the lower possible noise from the preamplifier stage is added to the input signal and the full output power is always available from the power amplifier. If the input signal is e.g. increased the SNR of the signals passing through the amplifier is correspondingly improved. This improves the performance of an optical network in which the amplifier is used.

**PCT**WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : H04B 10/17		A1	(11) International Publication Number: WO 98/36513
			(43) International Publication Date: 20 August 1998 (20.08.98)
(21) International Application Number: PCT/SE98/00255 (22) International Filing Date: 13 February 1998 (13.02.98) (30) Priority Data: 9700533-4 14 February 1997 (14.02.97) SE (71) Applicant (for all designated States except US): TELEFON-AKTIEBOLAGET LM ERICSSON (publ) [SE/SE]; S-126 25 Stockholm (SE). (72) Inventors; and (75) Inventors/Applicants (for US only): BONNEDAL, Dag [SE/SE]; Savolaksvägen 20, S-122 37 Enskede (SE). SANDELL, Johan [SE/SE]; Stockholmsvägen 41, S-122 32 Enskede (SE). SUNDELIN, Magnus [SE/SE]; Kyrkvägen 20, S-182 74 Stocksund (SE). (74) Agents: LINDÉN, Stefan et al.; Bergensträhle & Lindvall AB, P.O. Box 17704, S-118 93 Stockholm (SE).		(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.	

(54) Title: OPTICAL FIBER AMPLIFIER HAVING VARIABLE GAIN



(57) Abstract

An optical amplifier device intended for WDM light signals comprises a preamplifier (3) and a power amplifier (11) of the optical fiber amplifier type, which are connected in series and have gain curves dependent on the wavelength. A controllable attenuator (5) is connected between the amplifiers (3 and 11) and is controlled by a control device (7). The signal input to the preamplifier (3) has a low power and is amplified to provide an output signal where the signals of the input channels have been amplified with different gains. The input signal of the power amplifier (11) then has a larger power resulting in a gain characteristic different from that of the preamplifier (3). By adapting the attenuation of the attenuator (5) for variations in the input signal the gain characteristic of the power amplifier (11) can be set so that the signal output from the amplifier device has a spectral dependence that is the same as the original spectral dependence obtained without variations. Also, the same spectral dependence can be maintained when the pump light power of the power amplifier is changed and then the total amplifier gain is changed, by adapting the attenuation of the attenuator (5) so that the gain of the power amplifier is not changed. In the amplifier the lower possible noise from the preamplifier stage is added to the input signal and the full output power is always available from the power amplifier. If the input signal is e.g. increased the SNR of the signals passing through the amplifier is correspondingly improved. This improves the performance of an optical network in which the amplifier is used.

OPTICAL FIBER AMPLIFIER HAVING VARIABLE GAIN

TECHNICAL FIELD

The present invention relates to an optical fiber amplifier having variable gain, to be used in particular in a WDM network, and also to a WDM network and a method of amplifying WDM light signals.

BACKGROUND

Optical fiber amplifiers have great advantages in optical wavelength multiplexed transmission systems (WDM systems), as they are capable of simultaneously amplifying a number of WDM channels.

Normally such amplifiers are operated in a saturated condition, this implying that they have an approximately constant output power that is independent of the input power. This further implies that the gain of the amplifier is inversely proportional to the input power. This is an advantage in most transmission systems, since amplifiers placed along a transmission path will then automatically adjust their gain to be equal to the losses between the amplifiers.

For WDM systems there is one problem related to this type of amplifier operation. The spectral dependence of the amplifier depends on the population inversion of the amplifying medium. An increasing inversion will shift the amplification towards shorter wavelengths and a gain tilt results. The gain in the saturated amplifier also depends on the degree of population inversion. This implies that the relative gain between the different WDM channels depends directly on the amplification of the amplifier. Gain variations will directly cause an imbalance of the gain between the channels and this will lead to different signal to noise ratios, SNR, at the receiver. The channel with the lowest SNR will set the limit for the performance of the whole system.

Normally an amplifier is dimensioned for one certain application, i.e. the input power level and the gain. When the system is installed and taken into operation the power levels have to be adjusted using attenuators. The remaining gain imbalance has to be handled by the system within the allowed performance margins. The whole system has to be dimensioned for the worst case where attenuations are maximal in the transmission paths between each amplifier although most of the attenuations might be significantly lower in the actual installation. The total capacity of the transmission system will thus be significantly lower than it potentially could have been.

Methods of providing amplification with equal output power for the different WDM channels have also been presented. The optical WDM spectrum could be demultiplexed,

the individual channel power levelled by a set of saturated amplifiers and finally multiplexed again, see U.S. patents US-A 5,452,116 and US-A 5,392,154. The active fiber could be cooled to cryogenic temperatures which will lead to the effect that the gain at each wavelength is saturated individually, so called Spectral Hole Burning, see U.S. patent US-A 5,345,332. A wavelength tuneable filter with a suitable characteristic could partly compensate for the changes, see the article by R. A. Betts et al., "Split-beam Fourier filter and its application in a gain-flattened EDFA", Opt. Fiber Communications Conf., TuP4, San Diego, 1995. In specially prepared active fibers the spectral changes have been shown to have a reduced gain dependence, see J. Nilsson, Y.W. Lee and W.H. Choe, "Erbium doped fibre amplifier with dynamic gain flatness for WDM", Electron. Lett., Vol. 31, pp. 1578 - 1579, 1995.

These prior methods seem to be costly or complicated or to have a low performance.

SUMMARY

It is an object of the invention to provide an optical amplifier having a variable total gain and a constant spectral dependence within an optical transmission band.

It is another object of the invention to provide an optical amplifier having a constant spectral dependence for a varying power of the input light.

It is another object of the invention to provide a method of amplifying incoming, wavelength multiplexed light signals so that the signals are amplified to produce amplified light signals, where the gain for the different signals has a constant spectral dependence for a varying power of the total incoming light and for a variable total gain.

The problem solved by the invention is thus how to construct an optical amplifier that has a good performance, e.g. has better signal-to-noise ratios for higher input signals than for low signals, and that can be built at a reasonable cost.

Thus, an optical amplifier is provided that has a constant spectral dependence within the optical transmission band of a WDM system while the total gain of the amplifier can be varied without impairing the noise figure or the output power of the amplifier. The remaining spectral gain differences can be equalised with a fixed spectral filter if desired for example for a WDM system. The operation of the amplifier is based on the observation that a gain tilt in one amplifier stage in a two stage optical fiber amplifier can be corrected by a corresponding gain tilt having an opposite sign in another amplifier stage. The amplifier can thus be designed as a two stage amplifier where the first amplifier stage operates as a preamplifier stage in a more or less saturated state. The

second stage of the amplifier operates as a power or booster amplifier stage in a fully saturated state with an almost constant output power. The gain of the second stage is adjusted by adjusting the power input to this stage in order to produce a gain tilt having a magnitude equal to and an opposite sign compared to the gain tilt of the preamplifier stage.

The adjustment of the input power of the second stage is preferably achieved by arranging a controllable optical attenuator placed between the two amplifier stages. This attenuator can be either manually or automatically controlled. An automatically controlled attenuator can be mechanically or directly electrically controlled by one of various known techniques.

The gain of the complete amplifier for a fixed input power can further be varied by varying the pump power to the power amplification stage and thereby varying the output power, the attenuation of the attenuator simultaneously then being varied correspondingly to maintain a constant gain of the output amplification stage.

The control of the attenuator can be done in one of various ways. For a manual attenuator the loss is adjusted at installation to be optimised for the actual loss of the line section preceding the amplifier. For an automatically controllable attenuator the loss can either be calculated from the measured input power using the well predictable behaviour of the amplifier, as e.g. presented in the paper by D. Bonnedal, "EDFA Gain, Described with a Black Box Model," in Optical Amplifiers and their Applications, 1996 Technical Digest (Optical Society of America, Washington DC, 1996), pp. 215 - 218, or the channel power of two or more channels can actually be measured at the output and the difference therebetween can be minimised by a controller algorithm. The channel power measurements can be made using one of several well known techniques such as imposing pilot tones of different frequencies on some or all channels and measuring the relative channel power by frequency discrimination in the electrical domain, see the published European patent application EP-A1 0 637 148 which corresponds to U.S. patent 5,463,487. Alternatively an analysis of the whole or part of the optical spectrum can be made by fixed or scanning optical filters, gratings or interferometers.

By placing an attenuator between the amplification stages the optimal performance of the two stages is not impaired. The lowest possible noise from the preamplifier stage is added to the signal in each case of operation and the full output power is always available from the power amplification stage. This means that if the loss between a pair of amplifiers is lowered the SNR is correspondingly improved. The full potential of the total optical transmission system can be utilised.

Additional objects and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The objects and advantages of the invention may be realized and obtained by means of the methods, processes, instrumentalities and combinations particularly pointed out in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

A complete understanding of the invention and of the above and other features thereof may be gained from a consideration of the following detailed description of a non-limiting embodiment presented hereinbelow with reference to the accompanying drawings, in which:

- Fig. 1 is a diagram illustrating a portion of an optical fiber network, and
- Fig. 2 is a block diagram of a constant spectral gain amplifier.

DETAILED DESCRIPTION

In Fig. 1 a portion of an optical fiber WDM network is shown having nodes 101. Each node is connected to another node through one input fiber 103 and one output fiber 105. The input fibers are connected to preamplifiers 107 and the output fibers are connected to booster or power amplifiers 109. The preamplifiers 107 and the boosters 109 are in turn connected to electrical output and input ports 111, 113 respectively which comprise demultiplexers and multiplexers (couplers) respectively. It may be required to set the amplifiers 107, 109 to have suitably adapted gains depending on the purpose of the amplifier and it may also be required to change the gain during operation of the network. However, for amplifiers of type fiber optical amplifiers containing fibers having a doping of the rare-earth metal erbium, the values of the gain for different wavelengths are not equal to each other and even the dependence of the gain on the wavelength changes when the gain is altered, what results in problems related to e.g. differing signal-to-noise ratios. Amplifiers having a constant spectral dependence are advantageously used in such nodes and also as line amplifiers in a fiber optical network and they can be constructed as will now be described with reference to Fig. 2.

In the block diagram of an optical amplifier in Fig. 2 which is suitable for use in a node 101 of the network portion of Fig. 1, light enters the optical amplifier on an optical fiber 1. The optical fiber is connected to a first fiber optical amplifier 3, which acts as a preamplifier stage amplifying the light received on the fiber 1. The preamplifier 3 has a fixed gain for providing a suitable output power for the expected input light power range. The output of the preamplifier stage 3 is provided to a controllable attenuator 5, which is connected to an electrical controller 7 and controlled thereby. The light attenuated by the attenuator 5 then enters a fixed wavelength flattening filter 9, which has its output

connected to a power amplification stage or booster stage 11 comprising an optical fiber amplifier having a variable output power. The flattening filter 9 is optional and is not required for the basic operation of the amplifier. In the case where it is not included, the output of the controllable filter 7 is connected directly to the input of the power amplification stage 11. The light output from the total amplifier device is obtained on the optical fiber 12 connected to the output terminal of the power amplifier stage 11.

The electrical controller 7 also receives signals from light detectors. Thus an input light power detector 13 has its input connected to a Y-coupler 15 placed in the fiber 1 entering the amplifier. An intermediate power detector 17 is connected to the fiber line between the optional flattening filter 9 and the power amplification stage 11 through a Y-coupler 19 spliced into the fiber between these devices. An output power detector 21 is connected to the output of the power amplification stage 11 through a Y-coupler 23 located in the output line 12. An optional spectrum analysing device 25 such as a spectral filter can be connected in the input line of the output power detector 21.

The operation of the amplifier of Fig. 2 will now be described. It is based on the fact that in an optical fiber amplifier such as that included in the preamplifier stage 3 and the power amplification stage 9 the gain can be written in a very good approximation as a linear combination or a linear interpolation of two known spectra, provided that the gain values are expressed in a logarithmic unit such as dB, see the paper by Dag Bonnedal cited above. The gain spectrum for an input power P_{in} can be written as

$$G_k(\lambda) = G_b(\lambda) + k(G_a(\lambda) - G_b(\lambda)) \quad [\text{dB-units}] \quad (1)$$

where k is a constant that is independent of the wavelength λ and $G_a(\lambda)$ and $G_b(\lambda)$ are the gain for other input power values. The constant k depends on the input power and on the pump power. For two identically constructed optical fiber amplifiers No. 1 and 2 the gain is

$$G_k(\lambda) = G_b(\lambda) + k_1(G_a(\lambda) - G_b(\lambda)) \quad [\text{dB-units}] \quad (2)$$

$$G_k(\lambda) = G_b(\lambda) + k_2(G_a(\lambda) - G_b(\lambda)) \quad [\text{dB-units}] \quad (3)$$

where k_1 and k_2 are constants depending on the input power of and the pump power of the respective amplifier. If the two amplifiers are connected in series and an attenuator having a flat attenuation of A dB is connected therebetween, the total gain will be

$$G_{tot}(\lambda) = 2 \cdot G_b(\lambda) - A + (k_1 + k_2) \cdot (G_a(\lambda) - G_b(\lambda)) \quad [\text{dB-units}] \quad (4)$$

Thus, first assume that the preamplifying and booster stages 3, 11 and the attenuator 5 which is supposed to have a flat attenuation, i.e. the same attenuation for all considered wavelengths, have been set to give a total gain curve according to Eq. (4). Then suppose, that the power input to the preamplifying stage 3 is changed, and then the gain therein is changed and the constant k_1 is changed to $(k_1 + \Delta k_1)$. The total gain of the amplifier is then also changed according to Eq. (4). The attenuation is automatically controlled to a new value $(A + \Delta A)$ by sending suitable signals from the controller 7 to the attenuator 5. The input power to the power amplification stage 11 is then changed resulting in a change of the constant k_2 to $(k_2 + \Delta k_2)$. The resulting gain is

$$G_{\text{tot}}(\lambda) = 2 \cdot G_b(\lambda) - (A + \Delta A) + (k_1 + k_2 + \Delta k_1 + \Delta k_2) \cdot (G_a(\lambda) - G_b(\lambda)) \text{ [dB-units]} \quad (5)$$

If here ΔA is adjusted, so that the condition $\Delta k_2 = -\Delta k_1$ is satisfied, the resulting gain is

$$G_{\text{tot}}(\lambda) = 2 \cdot G_b(\lambda) - A - \Delta A + (k_1 + k_2) \cdot (G_a(\lambda) - G_b(\lambda)) \text{ [dB-units]} \quad (6)$$

which means that the resulting gain is proportional to the previous, initial or set one and that thus the spectral dependence of the gain is essentially unchanged.

In another case, the pump light power input to the power amplification stage 11 is changed, resulting in a changed output power of the total amplifier and also a change of the constant k_2 in Eq. (1). The attenuation A of the attenuator 5 can then be varied to a new value A' , so that the gain still is k_2 of the power stage 11, resulting in a total gain of

$$G_{\text{tot}}(\lambda) = 2 \cdot G_b(\lambda) - A' + (k_1 + k_2) \cdot (G_a(\lambda) - G_b(\lambda)) \text{ [dB-units]} \quad (7)$$

which is also proportional to the originally set gain.

If the optional gain flattening filter 9 is used, it should ideally be designed to have the attenuation (at least within some considered wavelength band containing the WDM channels)

$$A_{\text{gf}}(\lambda) = -(2 \cdot G_b(\lambda) + (k_1 + k_2) \cdot (G_a(\lambda) - G_b(\lambda))) - A_{\text{gf0}} \text{ [dB-units]} \quad (8)$$

where A_{gf0} is a constant. This will result in a total gain of the complete amplifier which is independent on the wavelength.

The attenuator 5 is automatically and electrically controlled by the control unit 7 but could also be manually controlled. The gain of the complete amplifier for a fixed input power is

varied by varying the pump power of the optical fiber amplifier of the power amplification stage 11 or in other ways, e.g. as described in the Swedish patent application 9603337-8, see in particular the description of Fig. 6. Then the attenuation of the attenuator 5 is simultaneously varied correspondingly to maintain a constant gain of the power amplification stage 11 according to the discussion above (Eq. (7)) by using the signals of the detectors 17 and 21 sensing the input and output power of the power amplification stage 11. For the automatically controllable attenuator 5 the loss (attenuation) thereof can be calculated from the input power measured by the input detector 13 and the light power as measured by the intermediate detector 17 provided that the behaviour and setting of the preamplification stage 3 is known. In some cases an additional light detector may be needed sensing the power input to the controllable attenuator (and then also the output power of the preamplifier stage 3 which may assist in controlling the gain thereof).

For a variation of the input power of the amplifier, this is sensed by the input detector 13 and then the attenuation of the filter 5 is controlled to compensate the change by modifying its output signal so that also the gain of the power amplification stage 11 is changed, compare Eqs. (5) and (6). This control can be made by using only the known behaviour of the amplification stages 3, 11, where the gain and the constant k can be deducted from the respective input power sensed by the detectors 13 and 17, such as by using the functional relationship presented in the paper by Dag Bonnedal cited above, see Eq. (1) in this paper:

$$G = (G_0^{-\alpha} + (\frac{P_{lim}}{P_{in}})^{-\alpha})^{-\frac{1}{\alpha}} + L \quad [\text{linear units}] \quad (9)$$

for one considered wavelength, P_{in} being the input power, G_0 being the gain for an unsaturated amplifier, P_{lim} the maximum output power of the amplifier, α an exponent in the range of 0.5 - 1.5 and L a constant. The value k is then calculated from

$$k = \frac{G_k - G_b}{G_a - G_b} \quad [\text{dB-units}] \quad (10)$$

Alternatively, for having a feedback control of the attenuator 5 and the power amplification stage 11 in this case for a varying input power, in some way the spectral profile of the light output from the power amplification stage 11 must be determined and then be controlled to be proportional to that initially set, see Eqs. (5) and (6). It can be made by measuring the channel power of two or more WDM channels at the output by means of having the suitably adapted spectral filter 25 selecting these channels to the output light detector 21. In another embodiment, no spectral filter 25 is required but suitably chosen, different pilot tones have been imposed on the signals in the channels so that the individual channel powers can be measured by filtering the electrical signal obtained from the

light detector 21 around the frequencies of the pilot tones and then measuring the amplitudes of the tones.

Often different lengths of the amplifying fibers are used in the two stages to give the pre-amplifier stage a lower maximum gain in order to impose less noise and the power amplification stage a larger gain in order to obtain a higher efficiency. It will mean that the basic curves $G_a(\lambda)$ and $G_b(\lambda)$ in Eqs. (2) and (3) expressing the wavelength dependence are not quite identical to each other for the two amplifier stages, but still they may be sufficiently similar. Then an accurate control according to the description above cannot be made, but still, within a sufficiently narrow wavelength interval, e.g. between 1540 and 1560 nm or for wavelengths within an even more narrow band around a frequency of 1550 nm, the control can be made in a way achieving an approximately constant spectral dependence of the overall gain of the amplifier.

Additional advantages and modifications will readily occur to those skilled in the art. Therefore, the invention in its broader aspects is not limited to the specific details, representative devices and illustrated examples shown and described herein. Accordingly, various modifications may be made without departing from the spirit or scope of the general inventive concept as defined by the appended claims and their equivalents.

CLAIMS

1. An optical amplifying device comprising a first optical fiber amplifier, characterized by a second optical fiber amplifier and an attenuator connected between the second optical fiber amplifier and the first optical fiber amplifier, the second optical fiber amplifier being
5 connected to receive input light having a low total light power and to amplify the light to provide it to the first optical fiber amplifier through the attenuator, the amplification of the second fiber optical fiber amplifier and the attenuation of the attenuator being adapted to provide light having a significantly higher total light power to the first optical fiber amplifier.
- 10 2. An optical amplifying device according to claim 1, characterized by a control device connected to the attenuator for controlling the attenuation thereof, the control device being adapted to control, for a change of the input light power of the second fiber optical amplifier, the attenuation so that the gain of the first fiber optical amplifier is changed in such a way, that the light output from the first amplifier has the same spectral dependence
15 as before the change.
3. An optical amplifying device according to any of claims 1 - 2, characterized by a control device connected to the attenuator for controlling the attenuation thereof, the control device being adapted to control, for a change of the pump light power to the first fiber optical amplifier, the attenuation so that the gain of the first fiber optical amplifier is
20 unchanged.
4. An optical amplifying device according to any of claims 1 - 3, characterized by a gain flattening filter connected between the second and first amplifiers for providing a compensation of the spectral dependence so that the gain of the optical amplifying device will be substantially independent of the wavelength of the input light signal.
- 25 5. An optical amplifying device according to any of claims 1 - 4, characterized by light detectors connected to sense the power of the input and output light of the first amplifier and connected to provide signals to the control device for controlling the gain of the first amplifier and the attenuation of the attenuator.
6. An optical amplifying device according to any of claims 1 - 5, characterized by a light
30 detector provided with a filter connected to sense the power of the output light of the first amplifier at at least two different wavelengths and connected to provide a signal to the control device for controlling the gain of the first amplifier and the attenuation of the attenuator.

7. An optical amplifying device according to any of claims 1 - 6, characterized by a light detector connected to sense the power of the input light of the second amplifier and connected to provide a signal to the control device for controlling the gain of the first amplifier and the attenuation of the attenuator.

8. A fiber optical network for transmitting WDM signals comprising links connected to at least one optical amplifying device, characterized in that the amplifying device comprises two fiber optical amplifiers, a preamplifier and a power amplifier, the preamplifier receiving light on an input line and the power amplifier delivering light on an output line, an attenuator being connected between the output terminal of the preamplifier and the input terminal of the power amplifier for transmitting light therebetween, the preamplifier and the power amplifier producing a gain tilt of their output signals, a control device being adapted to control the attenuation of the attenuator, so that
- for a change of the input light power to the preamplifier, the gain of the power amplifier is changed in such a way, that the light output from the power amplifier has the same spectral dependence as before the change, and/or
 - for a change of the pump light power to the power amplifier, the gain of the power amplifier is unchanged.

9. A method of amplifying light signals travelling in an optical transmission link, the light signals being comprised in a plurality of channels, the wavelengths of the channels being different and close to each other, characterized by the steps of
- amplifying the light signals simultaneously in a first optical medium having a gain substantially being, in logarithmic units, a first linear combination of a first and a second gain characteristic which are functions of the wavelength,
 - attenuating the amplified light signals proportionally,
 - amplifying the attenuated light signals simultaneously in a second optical medium having a gain substantially being, in logarithmic units, a second linear combination of the first and second characteristics,
 - controlling the attenuation so that, for a change of the input light power to the first medium, the amplification in the second medium is changed in such a way, that the light output from the second medium has the same spectral dependence as before the change, and/or
 - controlling the attenuation so that, for a change of the light output from the second medium, the amplification of the second medium is unchanged.

Fig. 1

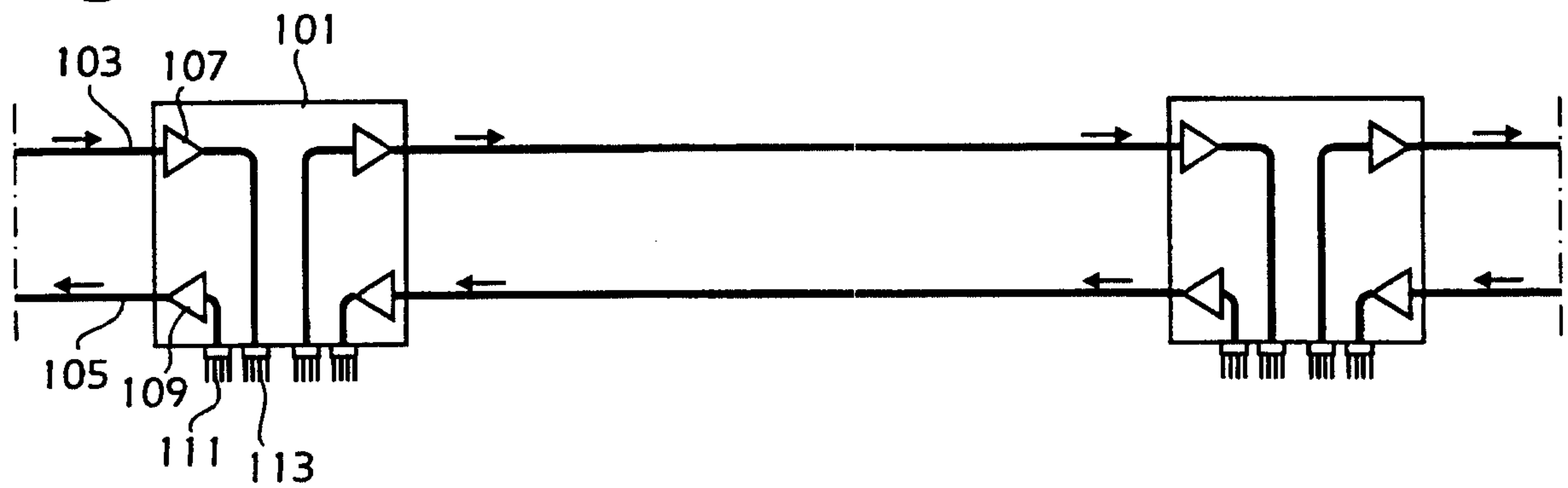


Fig. 2

