

Description

The present invention relates to optical amplifiers and to optical amplifier assemblies.

Optical amplifiers are used to amplify light, typically in the wavelength range 0.9 to 1.7 micrometres, and especially at approximately 1.3 and 1.55 micrometres.

Generally speaking, such amplifiers comprise semiconductor laser structures operated below the lasing threshold.

Optical amplifiers, or semiconductor laser amplifiers, are of particular interest at present because of their usefulness in fibre optic communications systems, particularly as optical preamplifiers or linear repeaters.

Any given optical amplifier can generally be classified as a Fabry-Perot (FP) amplifier, which is an injection laser driven at a current I just below the lasing threshold, or a travelling wave (TW) amplifier which is an injection laser with facet reflectivities which are, in theory, zero (or; in practice, very low). TW amplifiers are sometimes referred to as near-TW amplifiers, because in practice the facet reflectivities are around 10^{-2} to 10^{-3} .

The gain spectra for the two types of laser are quite different, the bandwidth of a TW amplifier being significantly greater than that of an FP amplifier. The term TW amplifier is used herein to refer to an optical amplifier which, when operated with a suitable bias, has a relatively smooth gain spectrum varying, over wavelengths of interest, by no more than 10dB and, usually, having no more than a 3dB ripple. Low facet reflectivities are one factor which lead to a smooth gain spectrum (wide bandwidth) and good gain; typically the product of the facet reflectivities is 10^{-4} or less.

Conventionally, an optical signal to be amplified is injected into one facet of a TW amplifier from an input optical fibre. The signal is amplified on propagation through the body of the amplifier and the amplified signal is then coupled from the opposite facet into an output optical fibre.

Accurate alignment of the ends of the optical fibres with the respective active areas of the amplifier facets is crucial to minimise signal losses. This alignment presents well-known practical difficulties in the construction of amplifier assemblies. Commonly, the alignment is achieved by operating the amplifier as a light source (ie increasing the bias current above the threshold value) and manipulating the optical fibre so as to maximise the optical power-coupled into the fibre. The optical fibre, usually mounted on a suitable carrier, may then be soldered or otherwise fixed in place. For an efficient optical coupling the alignment tolerance for the relative positioning of a single-mode optical fibre and the active area of the amplifier may be within ± 0.5 micrometres, or even ± 0.2 micromet-

res.

It is an aim of the invention to provide an amplifier which has enhanced performance, particularly gain, over conventionally configured optical amplifiers.

Additionally or alternatively, it is an object of the present invention to provide an amplifier assembly which can ease the alignment problems associated with the construction of conventional laser amplifier assemblies.

According to the present invention as defined in claim 1 an optical amplifier has first and second opposite facets provided with signal reflection means having, respectively, low and high reflectivities R_1 , R_2 , wherein the product $R_1 R_2$ is 5×10^{-4} or less and R_2 is in the range 0.3 to 1.0.

Preferably, the amplifier is adapted so that in use an optical signal enters via the first facet, is amplified on a first traverse of the amplifier, and reflected at the high reflectivity means to return along substantially the same path as that of the first traverse so as to exit through the first facet at substantially the point of entry.

The amplifier, ideally a TW amplifier, has R_1 as low as possible: preferably less than 5×10^{-4} , and more preferably 10^{-5} or even less. R_2 on the other hand is relatively high, typically in the range 0.5 to 1.0 and ideally between 0.85 and 1.00. The-product $R_1 R_2$ may be 10^{-4} or less, and preferably around 10^{-6} or less. R_1/R_2 may be around 10^{-3} or 10^{-4} and preferably around 10^{-5} or 10^{-6} , or less.

The invention also provides optical amplifier assemblies as defined in claims 8 and 9, comprising an optical amplifier and an optical waveguide located to transmit an input optical signal via the active area of the first facet, and to receive an amplified output signal.

Means such as a directional coupler, for example an X- or Y-coupler, may be provided to separate the output signal from the input signal.

Conveniently, the waveguide is a single mode fibre. It will be appreciated, however, that the optical waveguide may alternatively be a planar device, such as, for example, a lithium niobate waveguide device.

The very low reflectivity means is most conveniently provided by ensuring that the first facet has low reflectivity - for example by evaporation of an anti-reflection coating of suitable thickness and material. Skilled persons will already be familiar with appropriate techniques and materials, and information is also available in published literature. Materials currently used to provide low reflectivities (to 10^{-4} and below) are ZrO_2 and $ZrTiO_4$, and these can be refractive index-matched to the amplifier material, and evaporated to a suitable coating thickness (approximately $\lambda/4$).

The high reflectivity signal reflection means may be conveniently provided by deposition of a suitably reflective surface on the second facet. Aluminium or

chromium on gold deposits are examples.

It will be observed that the preferred configuration of an optical amplifier assembly according to the present invention has the advantage that the gain is significantly higher than with conventional optical amplifiers. Also, only a single precision alignment of an optical fibre with the active area of a semiconductor optical amplifier is required.

European Patent publication No. 0170313 A discloses a semiconductor laser device which may be used as an amplifier. The device is of the Fabry-Perot type, so both facet reflectivities will be high. The document refers to the difficulty of coupling single-mode fibres to the front and rear of a semi-conductor laser, and proposes halving the alignment steps by coupling fused input and output fibres to the same radiation-emitting surface of the laser. It is pointed out that the laser structure is symmetrical and it does not, in fact, have a front or a rear, so it does not matter which facet the fibres are aligned with.

D.M. Fye, in his paper "Practical Limitations on Optical Amplifier Performance", published in the Journal of Lightwave Technology, LT-2 (1984), No.4, pp 403-406, considers the performance of a travelling wave laser amplifier and a Fabry Perot laser amplifier with a view to assessing what improvements in receiver sensitivity can be achieved by their use. Detailed consideration is given to the practical performance limitations of two optical amplifier structures - a travelling wave device, which has notionally zero facet reflectivities, and a Fabry Perot device which has an input facet reflectivity of 0.01 and an output facet reflectivity of 0.3 and thus a reflectivity product of 3×10^{-3} . Fye points to disadvantages with both generic amplifier types, citing the polarisation sensitivity and temperature stabilisation requirements of the FP device, and the need for narrow linewidth filters with TW devices used at data rates of less than about 1Gbit/s. The use of SAGM APDs is suggested as a superior alternative to the use of laser amplifiers.

Another publication, UK Patent Application GB 2033648 A, discloses a special kind of optical amplifier, where light enters the semiconductor device through a low reflectivity film on a facet of the device, and is transmitted along a groove of high refractive index material, which follows a zig-zag path between the facets of the device, before emission through a second low reflectivity film on the opposite facet. Reflection within the device may be effected at a reflective film, or by total internal reflection. Light both enters and leaves the device through a low reflectivity surface as in a standard optical amplifier; the gain is increased by the series of internal reflections.

The invention will now be described in detail by way of example with reference to the accompanying drawings in which:

Figure 1 is a representation of a prior art amplifier configuration; and

Figure 2 is a schematic illustration of an embodiment according to the present invention.

Referring first to Figure 1, a conventional travelling wave optical amplifier device 1 comprises an amplifier chip 10 with an input optical fibre 11 and an output optical fibre 12, each aligned with the active areas of amplifier facets 13 and 14 respectively. In order to obtain a wide optical bandwidth (ie a low ripple of around 3dB across the pass band), both the facets 13 and 14 are provided with anti-reflection coatings having reflectivities of around 10^{-2} - 10^{-3} .

A TW optical amplifier according to the present invention is illustrated schematically in Figure 2. An amplifier chip 20 has facets 22 and 23. Facet 22 has a low-reflectivity coating having reflectivity around 10^{-4} or less, which is much lower than the standard reflectivities of TW optical amplifiers. The low reflectivity surface consists of an evaporated film of ZrO_2 or $ZrTiO_4$. The lower the reflectivity, the better the performance, so improvements in low-reflectivity coatings will lead to increased gain.

In contrast to the conventional assembly of Figure 1, facet 23 is provided with a high reflectivity coating. Aluminium or gold deposits are suitable for such coating, with reflectivities greater than 95% being routinely obtainable. Typically the reflectivity may be 95% or 99% or higher. When a metallic reflective coating is employed it is electrically isolated from the body of the amplifier using an appropriate intermediate isolating layer.

The amplifier assembly further comprises an optical fibre tail 25 which is aligned at one end (shown tapered) with the first facet 22 of the amplifier 20 and is spliced at the opposite end to a leg 26 of directional coupler 24. Optical fibres 21 and 30 are spliced to the ends 27 and 28 respectively of directional coupler 24.

In operation, input optical signals pass from the fibre 21 via the coupler 24 and fibre tail 25 into the amplifier 20. The signals are amplified on a first traverse of the amplifier 20, are then reflected back from facet 23, and are further amplified on a second traverse of amplifier 20 before being recoupled into fibre tail 25.

The amplified output signals are separated by the directional coupler 24 and exit via a leg 28 of the coupler into the output fibre 30.

The directional coupler 24 is illustrated as an X-coupler. The leg 29 of the directional coupler 24 may be utilised, for example, for such purposes as monitoring the input signal or for passing a proportion of the input signal to a second amplifier.

The configuration of Figure 2 also permits convenient monitoring of the amplifier for bias control purposes (eg. for stabilisation and avoidance of lasing action). This may be achieved by detecting a part of the small amount of optical power which passes the reflective coating on facet 23 using a photodiode 31. The signal from the photodiode may then be

employed in a conventional feedback control circuit.

It will be observed that light enters through the first, low reflectivity facet in the active region and traverses the amplifier within the active region of the device. After impinging on the second, high reflectivity facet a very large proportion of light is returned along the same path, or substantially the same path, as the first traverse. In practice, there may be a slight deviation of the order of 1° or 2°, but the light remains within the confined active region and exits very close to the original point of entry. Unlike conventional amplifiers, we have a very strong back reflection and it is because of this that the reflectivity of the first facet has to be much lower than would have been anticipated.

In the configuration of Figure 2, it will be noted that the amplifier length is effectively doubled over that of the conventional configuration. The amplification is correspondingly increased. A comparison of the relative performance of the two configurations may be approximated mathematically as follows:

To compare the properties of the two amplifier configurations it is first assumed that certain parameters are the same for both. In this analysis the bandwidths, the operating bias currents and the product of the facet reflectivities are considered equal.

For the conventional amplifier configuration of Figure 1, with a 3dB ripple across the pass band, the peak gain, G_1 is approximated by

$$G_1 = 1.45G_s(1-R_1)(1-R_2)$$

where R_1 and R_2 are the respective (low) reflectivities of facets 13 and 14, G_s is the gain from a single pass through the amplifier. It can also be shown that G_s may be approximated as

$$G_s = 0.17/(R_1R_2)^{0.5}$$

Taking $R_1=R_2=0.01$, for example, this gives

$$G_1 = 24.75 \text{ (or 13.9dB)}$$

This figure does not include coupling losses to and from the amplifier, which may be 5 or 6dB per facet.

For the amplifier configuration of Figure 2, the peak gain, G_2 , is given approximately by

$$G_2 = 1.45R_4G_s^2$$

where R_4 is the (high) reflectivity of facet 23. For the purposes of this comparison, we add the constraint $R_3R_4 = R_1R_2$, where R_3 is the (low) reflectivity of facet 22 (which is much lower than the reflectivities of conventional amplifiers); so that G_s is the same as before. Taking $R_4=0.9$, for example, then $R_3=1.1 \times 10^{-4}$ (both achievable reflectivities), which gives

$$G_2 = 363.6 \text{ (or 25.6dB)}$$

Thus, in this example, even allowing for a 6dB loss associated with the need for a coupler, there is a net improvement in gain (25.6-6-13.9 = 5.7dB) in using the reflective amplifier configuration of Figure 2 rather than the transmissive configuration of Figure 1.

If it were attempted to convert the conventional amplifier configuration of Figure 1 to that of Figure 2

by coupling an output fibre to input fibre 11, and increasing the reflectivity of facet 14, but without reducing the reflectivity of the input facet, then $G_s = 1.8$ for $R_2 = 0.9$ for facet 14. It follows that the gain of this amplifier is $G_1=1.45R_2G_s^2=4.2$ (or 6.2dB), which is much smaller than the gain $G_1=24.75$ of the amplifier before modification. The reflectivity values given in this example for high and low reflectivity surfaces of 0.9 and 0.01 respectively are of the same order as those currently used in practice for such surfaces.

The low reflectivity of facet 22 is therefore of considerable importance for increased gain. A reduced reflectivity of 10^{-3} (compared with a typical conventional reflectivity of around 10^{-2}) gives $G_s=5.7$ and an amplifier gain of 42 (or 16.2dB).

It will be apparent from the preceding analysis that performance of a semiconductor optical amplifier in the reflective configuration improves the lower the reflectivity of the first facet and the higher the reflectivity of the second facet. However, in selecting specific values for the low and high relative reflectivities for an amplifier assembly as described above the skilled person will have regard to those constraints appropriate to the situation, such as, for example, desired performance (eg gain, bandwidth, etc) versus production costs.

As mentioned previously, the cleaved end faces of a semiconductor laser amplifier have a raw uncoated reflectivity of approximately 32% (ie 0.32). So-called anti-reflection coatings are used to produce relatively lower reflectivities. Reflectivities below 3% (ie 0.03) are commonly achievable, and even two orders of magnitude below that (a reflectivity of 10^{-4}) is now achievable. A relatively high reflectivity for the second facet is obtainable, for example, by deposition or direct attachment of a mirrored surface. Alternatively, a high reflectivity surface may be positioned adjacent the relevant facet. Reflectivities above 70% (0.7) are easily obtained and figures above 95% (0.95) have also been routinely achieved.

As can be seen from the above analysis, the two facets typically have reflectivities two or more orders of magnitude different from one another, and ideally three or four orders of magnitude different.

The advantages of the reflective amplifier configuration of the above embodiment include:

1. Requirement for only a single fibre to laser coupling - compatible with standard laser packaging.
2. Additional gain owing to additional amplification path and facet reflectivities.
3. Convenient points provided for monitoring the input and amplified signals.

Claims

1. An optical amplifier comprising a medium cap-



employed in a conventional feedback control circuit.

It will be observed that light enters through the first, low reflectivity facet in the active region and traverses the amplifier within the active region of the device. After impinging on the second, high reflectivity facet a very large proportion of light is returned along the same path, or substantially the same path, as the first traverse. In practice, there may be a slight deviation of the order of 1° or 2° , but the light remains within the confined active region and exits very close to the original point of entry. Unlike conventional amplifiers, we have a very strong back reflection and it is because of this that the reflectivity of the first facet has to be much lower than would have been anticipated.

In the configuration of Figure 2, it will be noted that the amplifier length is effectively doubled over that of the conventional configuration. The amplification is correspondingly increased. A comparison of the relative performance of the two configurations may be approximated mathematically as follows:

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3. Convenient points provided for monitoring the input and amplified signals.

Claims

1. An optical amplifier comprising a medium cap-



able of providing optical amplification by laser action, the amplifier being provided with a single optical cavity within which said medium is confined, said medium having first and second opposed facets provided, respectively, with first and second signal reflection means defining said optical cavity and having, respectively, low and high reflectivities R_1 and R_2 , wherein the product $R_1 R_2$ is less than 5×10^{-4} and R_2 is in the range 0.3 to 1.0.

2. An optical amplifier as claimed in claim 1 adapted so that in use an optical signal which enters via the first reflection means is amplified on a first traverse of the amplifier, reflected at said second reflection means and returned along substantially the same path as that of the first traverse so as to exit through the first reflection means at substantially the point of entry.

3. An optical amplifier as claimed in claim 1 or claim 2, wherein the amplifier is a travelling wave amplifier.

4. An optical amplifier as claimed in any preceding claim, wherein R_1 is less than 10^{-4} .

5. An optical amplifier as claimed in any preceding claim, wherein R_2 is in the range 0.85 to 1.00.

6. An optical amplifier as claimed in any one of the preceding claims, wherein said signal reflection means comprise low and high reflectivity surfaces on the the first and second facets, respectively.

7. An optical amplifier as claimed in any one of claims 1 to 5, wherein said second signal reflection means comprises a high reflectivity surface provided adjacent the second facet.

8. An optical amplifier assembly comprising an amplifier as claimed in any preceding claim and an optical waveguide located to transmit an input optical signal via an active area of the first facet, and to receive an amplified output signal.

9. An optical amplifier assembly comprising: an amplifier which comprises a medium capable of providing optical amplification by laser action, first and second opposed facets defining the extent of said medium, and an optical cavity within which said medium is confined, the optical cavity comprising first and second opposed signal reflection means having respectively low and high reflectivities R_1 and R_2 , the product $R_1 R_2$ being less than 5×10^{-4} and R_2 being in the range 0.5 to 1.0, wherein said first facet defines said first signal reflection means and said second facet is positioned between said first facet and said second signal reflection means in an optical path of said optical cavity; and signal transmission means comprising an optical waveguide aligned with said first facet for the launching of optical signals into said optical cavity; whereby, in use, an input optical signal transmitted via said optical waveguide is amplified on a first traverse of the amplifier, is reflected by said second signal reflection means, and is further amplified by a second traverse of said amplifier and the further

amplified signal is subsequently coupled into said signal transmission means as an output signal.

10. An optical amplifier assembly as claimed in claim 8 or claim 9, including a directional coupler, one arm of which is associated with said waveguide, arranged to separate the output signal from the input signal.

11. An optical amplifier assembly according to any one of claims 8, 9 or 10, including amplifier control means comprising a controller and a detector positioned to detect a proportion of the amplified optical signal transmitted by the high reflectivity means and adapted to provide a monitor signal to the controller for controlling the amplifier gain.

Patentansprüche

1. Optischer Verstärker mit einem Medium, das eine optische Verstärkung durch Lasereinwirkung herbeiführt, wobei der Verstärker mit einem einzelnen optischen Hohlraum versehen ist, in welchem das Medium eingeschlossen ist und erste und zweite einander gegenüberliegende Facetten aufweist, die jeweils mit ersten und zweiten Signalreflexionsmitteln versehen sind, und welche den optischen Hohlraum definieren und einen jeweils niedrigen und hohen Reflexionsgrad R_1 und R_2 besitzen, wobei das Produkt $R_1 \times R_2$ kleiner als 5×10^{-4} ist und R_2 im Bereich von 0,3 bis 1,0 liegt.

2. Optischer Verstärker nach Anspruch 1, der so angepaßt ist, daß im Betrieb ein Lichtsignal, das durch die ersten Reflexionsmittel eintritt, beim ersten Durchgang durch den Verstärker verstärkt, an den zweiten Reflexionsmitteln reflektiert und entlang im wesentlichen des gleichen Strahlengangs wie beim ersten Durchgang zurückgeworfen wird, so daß es durch die ersten Reflexionsmittel im wesentlichen im Eintrittspunkt austritt.

3. Optischer Verstärker nach den Ansprüchen 1 oder 2, dadurch gekennzeichnet, daß der Verstärker ein Wanderwellenverstärker ist.

4. Optischer Verstärker nach einem beliebigen vorhergehenden Anspruch, dadurch gekennzeichnet, daß R_1 kleiner als 10^{-4} ist.

5. Optischer Verstärker nach einem beliebigen vorhergehenden Anspruch, dadurch gekennzeichnet, daß R_2 im Bereich von 0,85 bis 1,00 liegt.

6. Optischer Verstärker nach einem beliebigen vorhergehenden Anspruch, dadurch gekennzeichnet, daß die Signalreflexionsmittel auf den ersten bzw. zweiten Facetten Oberflächen mit jeweils niedrigem bzw. hohem Reflexionsgrad aufweisen.

7. Optischer Verstärker nach einem beliebigen Anspruch 1 bis 5, dadurch gekennzeichnet, daß das zweite Reflexionsmittel eine Oberfläche mit hohem Reflexionsgrad aufweist, die an die zweite Facette angrenzt.



8. Optische Verstärkeranordnung mit einem Verstärker nach einem beliebigen vorhergehenden Anspruch sowie mit einem Lichtwellenleiter, der so angeordnet ist, daß er ein Lichteingangssignal durch eine aktive Fläche der ersten Facette überträgt und ein verstärktes Ausgangssignal empfängt.

9. Optische Verstärkeranordnung mit: einem Verstärker, der ein Medium aufweist, das eine optische Verstärkung durch Lasereinwirkung herbeiführt, erste und zweite einander gegenüberliegende Facetten, welche die Ausdehnung des Mediums definieren, und einen optischen Hohlraum, in welchem das Medium eingeschlossen ist, wobei der optische Hohlraum erste und zweite einander gegenüberliegende Signalreflexionsmittel jeweils mit niedrigem und hohem Reflexionsgrad R_1 und R_2 aufweisen, wobei das Produkt $R_1 \times R_2$ kleiner als 5×10^{-4} ist und R_2 im Bereich von 0,5 bis 1,0 liegt, wobei die erste Facette die ersten Reflexionsmittel definiert und die zweite Facette in einem Strahlengang des optischen Hohlraumes zwischen der ersten Facette und den zweiten Signalreflexionsmitteln angeordnet ist; und mit Signalübertragungsmitteln, die einen mit der ersten Facette ausgefluchteten Lichtwellenleiter zum Einkoppeln von Lichtsignalen in den optischen Hohlraum aufweisen, wodurch im Betrieb ein durch den Lichtwellenleiter übertragenes Lichteingangssignal bei einer ersten Durchquerung des Verstärkers verstärkt, durch die zweiten Signalreflexionsmittel reflektiert und bei einer zweiten Durchquerung des Verstärkers weiter verstärkt wird, und das weiter verstärkte Signal anschließend als Ausgangssignal in die Signalübertragungsmittel einkoppelt.

10. Optische Verstärkeranordnung nach Anspruch 8 oder 9, mit einem Richtungskoppler, von dem ein Ast mit dem Wellenleiter verbunden ist, derart, daß das Ausgangssignal vom Eingangssignal getrennt wird.

11. Optische Verstärkeranordnung nach einem beliebigen Anspruch 8, 9 oder 10, mit Verstärkersteuerungsmitteln, die einen Regler und einen Detektor aufweisen, der so angeordnet ist, daß er einen Teil des von den Mitteln mit hohem Reflexionsgrad übertragenen verstärkten Lichtsignals erfaßt, und der so ausgelegt ist, daß er ein Überwachungssignal an den Regler zur Steuerung des Verstärkungsgewinns liefert.

Revendications

1. Un amplificateur optique comprenant un milieu susceptible de réaliser une amplification optique par effet laser, l'amplificateur comportant une cavité optique unique à l'intérieur de laquelle est confiné ledit milieu, ledit milieu comportant une première et une deuxième facettes opposées comportant, respectivement, un premier et un deuxième moyens de réflexion

de signaux définissant ladite cavité optique et possédant, respectivement, des réflectivités basse et haute R_1 et R_2 , le produit $R_1 R_2$ étant inférieur à 5×10^{-4} et R_2 étant dans la plage de 0,3 à 1,0.

2. Un amplificateur optique selon la revendication 1 adapté de telle manière que, en utilisation, un signal optique qui entre par l'intermédiaire du premier moyen de réflexion est amplifié sur une première traversée de l'amplificateur, est réfléchi au deuxième moyen de réflexion et est renvoyé sensiblement le long du même trajet que celui de la première traversée de façon à sortir à travers le premier moyen de réflexion sensiblement au point d'entrée.

3. Un amplificateur optique selon la revendication 1 ou la revendication 2, dans lequel l'amplificateur est un amplificateur à ondes voyageuses.

4. Un amplificateur optique selon une revendication précédente quelconque, dans lequel R_1 est inférieur à 10^{-4} .

5. Un amplificateur optique selon une revendication précédente quelconque, dans lequel R_2 est dans la plage de 0,85 à 1,00.

6. Un amplificateur optique selon l'une quelconque des revendications précédentes, dans lequel lesdits moyens de réflexion de signaux comprennent des surfaces à réflectivités basse et haute sur la première et la deuxième facettes, respectivement.

7. Un amplificateur optique selon l'une quelconque des revendications 1 à 5, dans lequel ledit deuxième moyen de réflexion de signaux comprend une surface de haute réflectivité disposée adjacente à la deuxième facette.

8. Un ensemble d'amplificateur optique comprenant un amplificateur selon une revendication précédente quelconque et un guide d'ondes optique situé de manière à transmettre un signal optique d'entrée par l'intermédiaire d'une zone active de la première facette et à recevoir un signal de sortie amplifié.

9. Un ensemble d'amplificateur optique comprenant: un amplificateur qui comprend un milieu susceptible de réaliser une amplification optique par effet laser, une première et une deuxième facettes opposées définissant l'étendue dudit milieu, et une cavité optique à l'intérieur de laquelle ledit milieu est confiné, la cavité optique comprenant un premier et un deuxième moyens opposés de réflexion de signaux possédant des réflectivités respectivement basse et haute R_1 et R_2 , le produit $R_1 R_2$ étant inférieur à 5×10^{-4} et R_2 étant dans la plage de 0,5 à 1,0, dans lequel ladite première facette définit ledit premier moyen de réflexion de signaux et ladite deuxième facette est positionnée entre ladite première facette et ledit deuxième moyen de réflexion de signaux dans un trajet optique de ladite cavité optique, et des moyens de transmission de signaux comprenant un guide d'ondes optique aligné avec ladite première facette pour lancer des signaux optiques dans ladite cavité optique; grâce à quoi, en utilisation, un signal



optique d'entrée transmis par l'intermédiaire du guide d'ondes optique est amplifié pendant une première traversée de l'amplificateur, est réfléchi par ledit deuxième moyen de réflexion de signaux, et est encore amplifié par une deuxième traversée dudit amplificateur, et le signal encore amplifié est ensuite couplé dans ledit moyen de transmission en tant que signal de sortie.

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10. Un ensemble d'amplificateur optique selon la revendication 8 ou la revendication 9, comprenant un coupleur directionnel, dont un bras est associé audit guide d'ondes, agencé pour séparer le signal de sortie du signal d'entrée.

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11. Un ensemble d'amplificateur optique selon l'une quelconque des revendications 8, 9 ou 10, comprenant un moyen de réglage d'amplificateur comprenant un dispositif de réglage et un détecteur positionné pour détecter une proportion du signal optique amplifié transmise par les moyens de haute réflectivité et apte à constituer un signal de surveillance pour le dispositif de réglage afin de régler le gain d'amplificateur.

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