

Description

This invention relates to amplifying optical signals.

It was proposed in articles starting on pages 84 and 90 of the Journal of The Optical Society of America A/Vol.2, No. 1/January 1985 to use a two-core optical fibre for amplifying an optical signal. The proposed method involved launching the optical signal into one core of the fibre and launching optical pump energy into the other core. The two cores were to differ in radius and/or refractive index so that the respective guidance paths which they defined would have different propagation constants. In particular, the propagation constants of the two cores would vary differently with wavelength, so that they would only be identical as one wavelength. The design was to be arranged so that that wavelength would correspond with the wavelength of the optical signal and hence through the known principle of optical coupling, repeatedly transfer between the two cores.

Amplification of the optical signal was to be achieved by non-linear effects such as three-wave mixing or stimulated Raman scattering, occurring at those regions where both the signal and the pump energy were present in the same core. The optical pumping energy was to be at wavelengths above 1000 nm and would need to be provided at a very high power level in order for the desired non-linear effects to operate.

The present invention aims to enable the use of lower pump energies, and also enable the use of lower wavelength pump energy, so that cheaper, more reliable, more economical and more readily available semiconductor sources can be used to supply the pump energy. To these ends, the invention uses stimulated emission in a core containing fluorescent material, for example a rare earth doped core.

From one aspect, the invention provides an optical fibre structure usable in amplifying optical signals, comprising a length of optical fibre which includes two uniformly spaced monomode optical cores located within a common cladding so as to provide two optical guidance paths, the optical characteristics of at least the cores being different such as to give the two guidance paths different propagation constants the values of which coincide for a predetermined coupling wavelength, characterised in that one of the cores includes a fluorescent material capable of producing stimulated emission at a wavelength substantially the same as said predetermined coupling wavelength.

From another aspect, the invention provides a method of amplifying an optical signal using an optical fibre structure as just defined, comprising arranging for the wavelength (λ_s) of the optical

signal, the fluorescent wavelength of said material in said one core, and said predetermined coupling wavelength all to be substantially the same, launching optical pump energy having a different wavelength (λ_p) into said one core to pump the fluorescent material, launching the optical signal into the other core so that the optical signal transfers repeatedly between the two cores due to optical coupling and, when in said one core, gives rise to stimulated emission substantially at its own wavelength from the fluorescent material thereby becoming amplified, and extracting the amplified optical signal from the fibre structure when it is in said other core.

In practice, launching light separately into the two cores of two-core fibre is not simple to achieve but can be done using lenses and/or specially prepared coupling fibres. From a further aspect, the invention aims to provide a device for amplifying an optical signal in which the input and output means are simplified.

From this aspect, there is provided a device for amplifying an optical signal, comprising an optical fibre structure in accordance with the invention as described above, having at at least one end a planar optic element which includes two optical paths which are optically matched with, and are at one end positioned in register with, respective ones of the fibre cores, the two optical paths of the planar element diverging in a direction away from the fibre to provide relatively widely spaced apart optical inputs leading to the fibre cores.

The invention also includes provision for electrically tuning the coupling wavelength between the cores, which enable the coupling wavelength to be brought into coincidence with the signal wavelength if this is not exactly achieved during manufacture of the fibre.

In order that the invention may be more clearly understood, some embodiments thereof will now be described, by way of example, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a graph showing the different variations with wavelength of the propagation constants of the optical guidance paths of a fibre shown in Figure 2;

Figure 2 shows (greatly shortened) an optical fibre having two cores which differ from each other so as to have the different propagation constants illustrated in Figure 1;

Figure 3 shows the pass-band for optical coupling, within the fluorescent spectrum, between the cores in the fibre of Figure 2;

Figure 4 shows a device in accordance with the invention incorporating a fibre as shown in Figure 2;

Figure 5 shows in cross-section a modified fibre structure which enables the centre wavelength of the pass-band to be tuned;

Figure 6 illustrates a stage in the manufacture of an optical fibre structure as shown in Figure 5; and

Figure 7 shows a further type of electrically tunable optical fibre structure.

The optical fibre 1 shown in Figure 2 has two optical cores 2 and 4 located within a common cladding 6. The cores 2 and 4 are uniformly spaced apart throughout the length of the fibre. Each of the cores provides a respective optical guidance path which extends laterally to each side of the core, and the spacing between the cores is made sufficiently small that their optical guidance paths will overlap. The cores 2 and 4 are designed for monomode operation at the wavelength of the optical signal to be amplified.

The material, diameter and refractive index profile of each core is selected, in a manner which in itself is known, such that the two cores have different propagation constants. Figure 1 shows by curve 8 the propagation constant (varying with wavelength) of core 2 and by curve 10 the propagation constant of core 4.

It can be seen from Figure 1 that the two propagation constants coincide for a wavelength λ_s . It is known that if light at that wavelength λ_s is introduced into one of the cores it will, by the known process of optical coupling which occurs when the propagation constants of the cores are equal, progressively transfer from the original core to the other one, and then back again, repeatedly. In fact, there is a pass-band of wavelengths centred on λ_s for which this occurs, the width of the pass-band being dependent on the relative angle of divergence between the curves 8 and 10 which can be controlled by adjusting the characteristics of the cores which have been referred to above.

In the optical fibre structure illustrated in Figure 2, an optical signal having wavelength λ_s equal to the optical coupling centre wavelength is introduced into core 2. The optical coupling effect causes the optical signal to transfer repeatedly from core 2 to core 4 and back as illustrated by the broken line 12 in Figure 2. In practice, the length of the fibre is likely to be of the order of 1 or 2 metres so that many hundreds of these transfers will occur as the optical signal traverses the length of the fibre.

The other core 4 has incorporated in it a fluorescent material capable of producing stimulated emission at a wavelength equal to or very close to λ_s . The preferred materials are fluorescent rare earth dopants, and especially erbium, which fluoresces, and produces stimulated emission, at a wavelength between 1530 and 1550 nm, this being

sufficiently close to the standard telecommunications optical information transmission wavelength of 1550 nm, that it enables the fibre to be used for amplification at that standard telecommunications wavelength. For operation at other standard telecommunications optical information transmission wavelengths such as 850 nm and 1300 nm, the cores must be designed to achieve the appropriate different coupling wavelength, and different dopants must be used.

Other rare earth elements can produce stimulated emission at various different wavelengths, for example neodymium at 1060 nm, and may be used to amplify optical signals at corresponding different wavelengths.

Returning to Figure 2, optical pump energy at a wavelength λ_p smaller than λ_s is launched into core 4 at one or both ends depending upon how much amplification is required. The pump energy may or may not be monomode in core 4. The optical pump energy raises electrons of the rare earth material in core 4 to a high energy level, from which they can fall to a lower level thus generating the fluorescent spectrum. The spontaneous fluorescent emission produced just by the application of the pump energy to the core 4 will have a relatively broad spectrum as illustrated by the broken line 14 in Figure 3 and only the limited quantity falling within the optical coupling pass-band 16 will be able to escape into core 2 through the optical coupling effect. This filtering action significantly reduces noise in the signal core 2 due to the noisy spontaneous emission in the amplifying core 4, relative to the amount of noise present in the output from known single core rare earth doped amplifying fibres.

Additionally, and to a far greater extent, at all the positions where the optical signal at λ_s is travelling in core 4 it causes stimulated emission from the pump rare earth atoms, the stimulated emission being centred on the same wavelength λ_s as the spontaneous fluorescent emission just referred to and being coherent with the optical signal which stimulates it. Consequently, the optical signal becomes progressively more amplified as it travels along the length of the fibre. The fibre length is determined such that at the end of the fibre the amplified optical signal is travelling entirely in core 2 and can therefore be extracted from the fibre free of all spontaneously emitted fluorescent radiation except for that limited amount lying within the pass-band 16. The optical pump energy, being at the smaller wavelength λ_p does not get coupled into core 2 and remains confined to core 4 as does that part of the spontaneous fluorescent emission lying between curves 14 and 16.

By way of example, the outside diameter of the fibre may be in the region of 125 μm and the

diameter of each core in the region of 3 to 20 μm .

Figure 4 shows a device, including a length of optical fibre 1 as just described, at each end of which there is secured a respective planar optic element 18,20. Each optic element 18,20 includes two optical paths 18a,18b,20a,20b. Paths 18a and 20a are in register with the optical core 4 of the fibre and are optically matched with it as closely as possible in terms of dimensions and refractive index distribution thus minimising reflections at the interfaces that could cause undesirable lasing action. The other optical paths 18b and 20b of the planar elements are similarly in register with, and optically matched with, the core 2.

The paths 18a and 18b diverge from each other in a direction away from the fibre so as to provide relatively widely spaced apart optical inputs to which, for example, respective single core fibres 22 and 24 can conveniently be coupled in known manner so that pump energy can be launched into the fibre 1 from fibre 22 via planar element 18 and the optical signal to be amplified can be launched into fibre 1 from fibre 24 via planar element 18. Further single core fibres 26 and 28 can be coupled to planar element 20 respectively for launching further pump energy into core 4 of fibre 1 and for extracting the amplified optical signal from core 2 of fibre 1. If only one pump energy input is required, planar element 20 may be omitted and fibre 28 can be connected direct in register with core 2. Alternatively planar element 18 may be omitted and fibre 24 connected direct in register with core 2, the pump energy then being introduced only through fibre 26.

Figure 5 shows a cross-sectional view through a two-core fibre similar to that shown in the previous figures but in which provision is made for a limited degree of electrical tuning of the centre wavelength of the optical coupling pass-band. This enables the centre wavelength to be adjusted after manufacture if such adjustment should be needed so as to match the centre wavelength to the wavelength of the optical signal to be amplified.

In Figure 5 two metal electrodes 30 and 32 are incorporated into the structure of the fibre itself. Both of the electrodes are located such that both of the cores 2 and 4 lie between them. Although the siliceous material which is used for the cores 2 or 4 will exhibit only a relatively small Kerr effect in response to the application of an electrical field, nevertheless the field strength can be made relatively high in relation to the voltage applied across the electrodes by incorporating the electrodes within the fibre itself. When a voltage is applied across the electrodes, the Kerr effect results in a change in the refractive index of each of the cores and consequently a shift in the propagation constants of both of them. Consequently, there is a correspond-

ing shift in the centre frequency of the coupling pass-band.

In fact, the Kerr effect causes a differential change in refractive index as between the light polarised perpendicular to the electrodes and that polarised parallel to the electrodes (i.e. vertically and horizontally in relation to the fibre as shown in Figure 4). The refractive index shift is greater for the light whose plane of polarisation is perpendicular to the electrodes and to take advantage of the greater shift available with this polarisation, the fibre may be fed initially only with light having this polarisation. Alternatively, light polarised parallel to the electrodes may be filtered out at the output end of the fibre using an analyser, thus leaving only the light polarised perpendicular to the electrodes.

To further enhance the maximum frequency shift available, soft glasses (e.g. lead, crown or flint glass) may be used for the cores and cladding, these having a greater Kerr effect than the harder glasses usually used for optical fibre cores and cladding.

Figure 6 is useful in explaining the manufacture of a fibre structure as shown in Figure 5. Two core rods are manufactured, for example by depositing glass material having the appropriate characteristics for the particular core inside respective silica support tubes using a modified chemical vapour deposition (MCVD) process. Most of the support tube material is then etched away so as to leave relatively little cladding material on the central optical core material, since the optical cores will need to be relatively close together. The two core rods are then elongated whilst heated in an electric furnace and are drawn to a few millimetres diameter.

A high purity silica rod 34 which is initially of circular cross-section has flats 36 machined on opposite sides of it and two bores 38 and 40 ultrasonically machined axially through it.

The two drawn-down core rods, which are drawn down to a diameter which matches the bores 38 and 40 respectively, are then inserted in these bores and the composite assembly is inserted into a silica tube 42. The entire assembly is then drawn down to a diameter sufficiently small to ensure single mode operation at the optical signal wavelength.

The resulting fibre is as shown in Figure 5 but with spaces where the electrodes 30 and 32 are shown. These spaces are filled with a low melting point metal such as Wood's metal or an Indium/Gallium mixture, by enclosing the fibre length in a heated enclosure with one end in the liquid metal and simultaneously applying pressure at that end and vacuum at the opposite end of the fibre. The liquid metal is thus pumped into the spaces and solidifies to form the electrodes 30 and

32 when the fibre is cooled.

Figure 7 shows a further form of electrically tunable fibre in accordance with the invention in which only core 4 is located between electrodes, these being indicated by reference numeral 44. This structure may be manufactured in a similar way to that of Figure 6 but, instead of flats 36 being machined on the rod 34, two additional holes are bored through it ultrasonically on each side of the bore 40. These are then filled with metal to form the electrodes 44 after the fibre has been drawn. With this structure, the application of a voltage between the electrodes 44 will shift only one of the propagation constants so that a different, and potentially greater, amount of centre wavelength shift can be obtained for a given applied voltage, compared with the Figure 5 structure.

For the purpose of applying a voltage across the electrodes 30 and 32 in Figure 5, or 44 in Figure 7, part of the cladding of the fibre may be locally etched away using hydrogen fluoride until surface regions of the electrodes are exposed, and then fine electrical leads 46 may be ultrasonically welded to the electrodes, this being illustrated in Figure 7 where the part of the cladding removed by etching is illustrated in broken lines.

Figure 7 also shows in broken lines a second pair of electrodes 48 which may be located on opposite sides of the core 2, so that the propagation constants of the two cores may be controlled independently of each other if desired.

Claims

1. An optical fibre structure usable in amplifying optical signals, comprising a length of optical fibre (1) which includes two uniformly spaced monomode optical cores (2,4) located within a common cladding (6) so as to provide two optical guidance paths, the optical characteristics of at least the cores being different such as to give the two guidance paths different propagation constants the values of which coincide for a predetermined coupling wavelength, characterised in that one of the cores (4) includes a fluorescent material capable of producing stimulated emission at a wavelength substantially the same as said predetermined coupling wavelength.
2. An optical fibre structure as claimed in claim 1, characterised in that the fluorescent material will produce stimulated emission substantially at a wavelength used in optical telecommunications transmissions.
3. An optical fibre structure as claimed in claim 1 or claim 2, characterised in that the length of optical fibre has a length equal to an integral number times the coupling beat length, between the two cores, of optical energy having a wavelength used in optical telecommunications transmission.
4. An optical fibre structure as claimed in any one of claims 1 to 3, characterised in that the fluorescent material is erbium.
5. An optical fibre structure as claimed in claim 1, characterised in that the fluorescent material is a rare earth dopant.
6. An optical fibre structure as claimed in claim 5, characterised in that the rare earth dopant is neodymium.
7. An optical fibre structure as claimed in any one of the preceding claims characterised in that two electrodes (30,32;44) are provided within the cladding and are located with at least one core (4) between them for applying an electrical field to that core whereby to alter its propagation constant by the electro-optic effect and hence to alter said coupling wavelength, the structure thereby being tunable.
8. An optical fibre structure as claimed in Claim 7 characterised in that the two electrodes (30,32) are located with both cores (2,4) between them.
9. An optical fibre structure as claimed in Claim 7, characterised in that the two electrodes (44) are located with only one (4) of the cores between them.
10. An optical fibre structure as claimed in Claim 9, comprising two further electrodes (48) located with the other core (2) between them.
11. An optical fibre structure as claimed in any one of claims 7 to 10 wherein at least said one core is of a soft glass exhibiting a relatively large electro-optic effect.
12. An optical fibre structure as claimed in Claim 11 wherein the common cladding is of a soft glass exhibiting a relatively large electro-optic effect.
13. A method of amplifying an optical signal using an optical fibre structure as claimed in any preceding claim, comprising arranging for the wavelength (λ_s) of the optical signal, the fluorescent wavelength of said material in said one core, and said predetermined coupling



32 when the fibre is cooled.

Figure 7 shows a further form of electrically tunable fibre in accordance with the invention in which only core 4 is located between electrodes, these being indicated by reference numeral 44. This structure may be manufactured in a similar way to that of Figure 6 but, instead of flats 36 being machined on the rod 34, two additional holes are bored through it ultrasonically on each side of the bore 40. These are then filled with metal to form the electrodes 44 after the fibre has been drawn. With this structure, the application of a voltage between the electrodes 44 will shift only one of the propagation constants so that a different, and potentially greater, amount of centre wavelength shift can be obtained for a given applied voltage, compared with the Figure 5 structure.

For the purpose of applying a voltage across the electrodes 30 and 32 in Figure 5, or 44 in Figure 7, part of the cladding of the fibre may be locally etched away using hydrogen fluoride until surface regions of the electrodes are exposed, and then fine electrical leads 46 may be ultrasonically welded to the electrodes, this being illustrated in Figure 7 where the part of the cladding removed by etching is illustrated in broken lines.

Figure 7 also shows in broken lines a second pair of electrodes 48 which may be located on opposite sides of the core 2, so that the propagation constants of the two cores may be controlled independently of each other if desired.

Claims

1. An optical fibre structure usable in amplifying optical signals, comprising a length of optical fibre (1) which includes two uniformly spaced monomode optical cores (2,4) located within a common cladding (6) so as to provide two optical guidance paths, the optical characteristics of at least the cores being different such as to give the two guidance paths different propagation constants the values of which coincide for a predetermined coupling wavelength, characterised in that one of the cores (4) includes a fluorescent material capable of producing stimulated emission at a wavelength substantially the same as said predetermined coupling wavelength.
2. An optical fibre structure as claimed in claim 1, characterised in that the fluorescent material will produce stimulated emission substantially at a wavelength used in optical telecommunications transmissions.
3. An optical fibre structure as claimed in claim 1 or claim 2, characterised in that the length of

optical fibre has a length equal to an integral number times the coupling beat length, between the two cores, of optical energy having a wavelength used in optical telecommunications transmission.

4. An optical fibre structure as claimed in any one of claims 1 to 3, characterised in that the fluorescent material is erbium.
5. An optical fibre structure as claimed in claim 1, characterised in that the fluorescent material is a rare earth dopant.
6. An optical fibre structure as claimed in claim 5, characterised in that the rare earth dopant is neodymium.
7. An optical fibre structure as claimed in any one of the preceding claims characterised in that two electrodes (30,32;44) are provided within the cladding and are located with at least one core (4) between them for applying an electrical field to that core whereby to alter its propagation constant by the electro-optic effect and hence to alter said coupling wavelength, the structure thereby being tunable.
8. An optical fibre structure as claimed in Claim 7 characterised in that the two electrodes (30,32) are located with both cores (2,4) between them.
9. An optical fibre structure as claimed in Claim 7, characterised in that the two electrodes (44) are located with only one (4) of the cores between them.
10. An optical fibre structure as claimed in Claim 9, comprising two further electrodes (48) located with the other core (2) between them.
11. An optical fibre structure as claimed in any one of claims 7 to 10 wherein at least said one core is of a soft glass exhibiting a relatively large electro-optic effect.
12. An optical fibre structure as claimed in Claim 11 wherein the common cladding is of a soft glass exhibiting a relatively large electro-optic effect.
13. A method of amplifying an optical signal using an optical fibre structure as claimed in any preceding claim, comprising arranging for the wavelength (λ_s) of the optical signal, the fluorescent wavelength of said material in said one core, and said predetermined coupling



wavelength all to be substantially the same, launching optical pump energy having a different wavelength (λ_p) into said one core to pump the fluorescent material, launching the optical signal into the other core so that the optical signal transfers repeatedly between the two cores due to optical coupling and, when in said one core gives rise to stimulated emission substantially at its own wavelength from the fluorescent material thereby becoming amplified, and extracting the amplified optical signal from the fibre structure when it is in said other core.

14. A method of amplifying an optical signal as claimed in claim 13 characterised in that the optical pump energy is launched into both ends of said one core.

15. A method of amplifying an optical signal as claimed in claim 13 or claim 14, comprising applying an electrical field to at least one of the cores whereby to alter its propagation constant by the electro-optic effect and hence alter said coupling wavelength.

16. A device for amplifying an optical signal, comprising an optical fibre structure as claimed in any one of claims 1 to 12 having, at at least one end a planar optic element (18,20) which includes two optical paths (18a, 18b) which are optically matched with, and are at one end positioned in register with, respective ones (4,2) of the fibre cores, the two optical paths of the planar element diverging in a direction away from the fibre, whereby to provide relatively widely spaced apart optical input or output means leading to or from the fibre cores.

17. A device as claimed in claim 16 characterised in that the optical fibre structure has such a planar optic element at each end.

18. A device as claimed in claim 16 or claim 17 wherein, in the fibre, two electrodes (30,32;44) are provided within the cladding and are located with at least one core (4) between them for applying an electrical field to that core whereby to alter its propagation constant by the electro-optic effect and hence to alter said coupling wavelength, the device thereby being tunable.

Patentansprüche

1. Optische Faserstruktur zur Verstärkung optischer Signale mit einer bestimmten Länge einer optischen Faser (1), die zwei gleichmäßig

beabstandete monomode optische Kerne (2, 4) enthält, die innerhalb einer gemeinsamen Umhüllung (6) angeordnet sind, so daß zwei optische Wege entstehen, wobei die optischen Eigenschaften mindestens der Kerne sich voneinander unterscheiden, so daß die zwei Wege unterschiedliche Ausbreitungskonstanten aufweisen, deren Werte bei einer vorbestimmten Kopplungswellenlänge zusammenfallen, dadurch gekennzeichnet, daß einer der Kerne (4) ein fluoreszierendes Material enthält, welches eine stimulierte Emission bei einer Wellenlänge erzeugt, die im wesentlichen die gleiche ist, wie die vorbestimmte Kopplungswellenlänge.

2. Optische Faserstruktur nach Anspruch 1, dadurch gekennzeichnet, daß das fluoreszierende Material eine stimulierte Emission im wesentlichen bei einer Wellenlänge erzeugt, die bei optischen Telekommunikationssystemen verwendet wird.

3. Optische Faserstruktur nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß die Länge der optischen Faser gleich einem ganzzahligen vielfachen der zwischen den zwei Kernen auftretenden Kopplungs-Schwebungslänge der optischen Energie ist, die eine bei optischen Telekommunikationssystemen verwendete Wellenlänge aufweist.

4. Optische Faserstruktur nach mindestens einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, daß das fluoreszierende Material Erbium ist.

5. Optische Faserstruktur nach Anspruch 1, dadurch gekennzeichnet, daß das fluoreszierende Material ein Dotierstoff aus seltenen Erden ist.

6. Optische Faserstruktur nach Anspruch 5, dadurch gekennzeichnet, daß der Dotierstoff Neodym ist.

7. Optische Faserstruktur nach mindestens einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß zwei Elektroden (30, 32; 44) innerhalb der Umhüllung vorgesehen und so angeordnet sind, daß mindestens ein Kern (4) zwischen ihnen liegt, um ein elektrisches Feld an diesen Kern anzulegen und durch den elektrooptischen Effekt seine Ausbreitungskonstante zu ändern, so daß sich auch die Kopplungs-Wellenlänge ändert und die Struktur somit abstimmbar ist.



8. Optische Faserstruktur nach Anspruch 7, dadurch gekennzeichnet, daß die zwei Elektroden (30, 32) so angeordnet sind, daß beide Kerne (2, 4) zwischen ihnen liegen.

9. Optische Faserstruktur nach Anspruch 7, dadurch gekennzeichnet, daß die zwei Elektroden (44) so angeordnet sind, daß nur einer der Kerne (4) zwischen ihnen liegt.

10. Optische Faserstruktur nach Anspruch 9, gekennzeichnet durch zwei weitere Elektroden (48), zwischen denen der andere Kern (2) liegt.

11. Optische Faserstruktur nach mindestens einem der Ansprüche 7 bis 10, dadurch gekennzeichnet, daß mindestens einer der Kerne aus weichem Glas besteht und einen relativ großen elektrooptischen Effekt erzeugt.

12. Optische Faserstruktur nach Anspruch 11, dadurch gekennzeichnet, daß die gemeinsame Umhüllung aus weichem Glas ist und einen relativ großen elektrooptischen Effekt aufweist.

13. Verfahren zur Verstärkung optischer Signale unter Verwendung einer optischen Faserstruktur gemäß mindestens einem der vorhergehenden Ansprüche, gekennzeichnet durch Auswahl einer Wellenlänge (λ_s), die für das optische Signal, die fluoreszierende Wellenlänge des Materials des einen Kerns und die vorbestimmte Kopplungs-Wellenlänge im wesentlichen gleich ist, Einspeisung optischer Pumpleistung mit einer abweichenden Wellenlänge (λ_p) in den einen Kern, um das fluoreszierende Material zu pumpen, Einspeisung des optischen Signals in den anderen Kern, so daß das optische Signal wiederholt zwischen den zwei Kernen aufgrund optischer Kopplung übertragen wird und in dem einen Kern eine stimulierte Emission des fluoreszierenden Materials bei im wesentlichen seiner eigenen Wellenlänge erzeugt und dadurch verstärkt wird, sowie Auskoppeln des verstärkten optischen Signals aus der Faserstruktur, wenn dieses sich in dem anderen Kern befindet.

14. Verfahren zur Verstärkung eines optischen Signals nach Anspruch 13, dadurch gekennzeichnet, daß die optische Pumpleistung in beide Enden des einen Kerns eingespeist wird.

15. Verfahren zur Verstärkung eines optischen Signals nach Anspruch 13 oder 14, gekennzeichnet durch Anlegen eines elektrischen Feldes an mindestens einen der Kerne zur Änderungen seiner Ausbreitungskonstante aufgrund des elektrooptischen Effektes und damit zur Änderung seiner Kopplungs-Wellenlänge.

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16. Vorrichtung zur Verstärkung eines optischen Signals mit einer optischen Faserstruktur nach mindestens einem der Ansprüche 1 bis 12 mit einem planaren optischen Element (18, 20) an mindestens einem Ende, welches zwei optische Wege (18a, 18b) aufweist, die optisch an die entsprechenden Faserkerne (4, 2) angepaßt und an einem Ende mit diesen ausgerichtet sind, wobei die zwei optischen Wege des planaren Elementes in einer von der Faser wegweisenden Richtung divergieren, so daß ein relativ groß beabstandeter optischer Eingang oder Ausgang entsteht, der zu den Faserkernen hin - bzw. von diesen wegführt.

17. Vorrichtung nach Anspruch 16, dadurch gekennzeichnet, daß die optische Faserstruktur an jedem Ende ein solches planares optisches Element aufweist.

18. Vorrichtung nach Anspruch 16 oder 17, dadurch gekennzeichnet, daß in der Faser zwei Elektroden (30, 32; 44) innerhalb der Umhüllung vorgesehen sind, die so angeordnet sind, daß mindestens ein Kern (4) zwischen ihnen liegt, um ein elektrisches Feld an diesen Kern anzulegen, so daß sich aufgrund des elektrooptischen Effektes seine Ausbreitungskonstante und damit die Kopplungs-Wellenlänge ändert und die Vorrichtung abstimmbar ist.

Revendications

1. Une structure de fibres optiques utilisable pour l'amplification de signaux optiques, comprenant une longueur de fibre optique (1) comprenant deux coeurs optiques monomode espacés (2, 4) placés dans une gaine commune (6), de manière à former deux trajets de guidage optiques, au moins les caractéristiques optiques des coeurs étant différentes, de manière à donner aux deux trajets de guidage des constantes de propagation différentes, dont les valeurs coïncident pour une longueur d'onde de couplage prédéterminée, caractérisée en ce que l'un des coeurs (4) comprend un matériau fluorescent, capable de produire une émission stimulée à une longueur d'onde sensiblement équivalente à ladite longueur d'onde de cou-



plage prédéterminée.

2. Une structure de fibres optiques selon la revendication 1, caractérisée en ce que le matériau fluorescent produit une émission stimulée sensiblement à la longueur d'onde utilisée dans les transmissions de télécommunication par fibres optiques.

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3. Une structure de fibres optiques selon la revendication 1 ou 2, caractérisée en ce que la longueur de la fibre optique est égale à un nombre entier de longueurs de battements de couplage entre les deux coeurs, dont l'énergie optique a une longueur d'onde utilisée dans les transmissions de télécommunication par fibres optiques.

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4. Une structure de fibres optiques selon l'une quelconque des revendications 1 à 3, caractérisée en ce que le matériau fluorescent est de l'erbium.

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5. Une structure de fibres optiques selon la revendication 1, caractérisée en ce que le matériau fluorescent est un dopant de terres rares.

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6. Une structure de fibres optiques selon la revendication 5, caractérisée en ce que le dopant de terres rares est du néodymium.

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7. Une structure de fibres optiques selon l'une quelconque des précédentes revendications, caractérisée en ce que deux électrodes (30, 32; 44) sont prévues dans la gaine et sont positionnées de manière qu'au moins un coeur (4) soit disposé entre les deux pour appliquer un champ électrique à ce coeur afin de modifier sa constante de propagation par effet électro-optique et, par suite, de modifier ladite longueur d'onde de couplage, la structure étant ainsi accordable.

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8. Une structure de fibres optiques selon la revendication 7, caractérisée en ce que les deux électrodes (30, 32) sont disposées de manière que les deux coeurs (2, 4) soient placés entre elles.

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9. Une structure de fibres optiques selon la revendication 7, caractérisée en ce que les deux électrodes (44) sont disposées de manière que l'un des coeurs (4) seulement soit placé entre elles.

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10. Une structure de fibres optiques selon la revendication 9, comprenant deux électrodes supplémentaires (48), disposées de manière

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que l'autre coeur (2) soit placé entre elles.

11. Une structure de fibres optiques selon l'une quelconque des revendications 7 à 10, dans laquelle au moins ledit coeur soit un verre tendre présentant un effet électro-optique relativement important.

12. Une structure de fibres optiques selon la revendication 11, dans laquelle la gaine commune est en verre tendre présentant un effet électro-optique relativement important.

13. Un procédé d'amplification d'un signal optique utilisant une structure de fibres optiques selon l'une quelconque des précédentes revendications, comprenant l'agencement de la longueur d'onde (λ_s) du signal optique, la longueur d'onde fluorescente dudit matériau dans ledit coeur, et ladite longueur d'onde de couplage prédéterminée, toutes étant sensiblement les mêmes, l'application d'une énergie de pompage optique possédant une longueur d'onde différente (λ_p) dans ledit coeur pour pomper le matériau fluorescent, l'émission du signal optique dans l'autre coeur, de manière à transférer répétitivement le signal optique entre les deux coeurs par suite du couplage optique et, quand il est dans ledit coeur, à provoquer une émission stimulée sensiblement à sa propre longueur d'onde du matériau fluorescent qui se trouve ainsi amplifiée, et l'extraction du signal optique amplifié de la structure de fibres lorsqu'il se trouve dans ledit autre coeur.

14. Un procédé d'amplification d'un signal optique selon la revendication 13 caractérisé en ce que l'énergie de pompage optique est appliquée aux deux extrémités dudit coeur.

15. Un procédé d'amplification d'un signal optique selon la revendication 13 ou 14, comprenant l'application d'un champ électrique sur au moins l'un des coeurs, de manière à modifier sa constante de propagation par un effet électro-optique et, par suite, de modifier ladite longueur d'onde de couplage.

16. Un dispositif d'amplification d'un signal optique comprenant une structure de fibres optiques selon l'une quelconque des revendications 1 à 12 comprenant, au moins à une extrémité, un élément optique planaire (18, 20) comportant deux trajets optiques (18a, 18b) accordés optiquement et, au moins à une extrémité, disposés de manière à correspondre avec les coeurs respectifs (4, 2), des coeurs de fibres, les deux trajets optiques de l'élément planaire



divergeant dans une direction allant en s'écartant de la fibre, de manière à ménager des moyens d'entrée ou de sortie optiques relativement espacés, allant vers les coeurs de fibres ou venant de ceux-ci.

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17. Un dispositif selon la revendication 16, caractérisé en ce que la structure de fibres optiques comprend un élément optique planaire à chaque extrémité.

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18. Un dispositif selon la revendication 16 ou 17, dans lequel il est prévu dans la fibre deux électrodes (30, 32 ; 4) dans la gaine et il est placé au moins un coeur (4) entre les deux pour appliquer un champ électrique à ce coeur, de manière à modifier sa constante de propagation par effet électro-optique et, par suite, de modifier ladite longueur d'onde de couplage, le dispositif étant ainsi accordable.

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