

Description

This invention relates to lasers and to optical amplifiers.

There is growing interest in optical communication systems utilising the 850 nm communications window provided by silica optical fibres.

One known approach to providing optical sources or amplifiers is to use a semiconductor laser as the source of a pump signal for an optical fibre laser or amplifier which then emits or amplifies an optical signal at a wavelength which may be the same as or different to that of the pump. This has the advantage of providing ready access to the signal wavelength in a manner which can take advantage of the relative low cost, high efficiency and commercial availability of laser diodes.

Lasers and amplifiers are known which depend for their operation on lasing transitions between upper and lower lasing levels of ions in a lasing medium each of which lies above the levels of the ions' ground state. If the average lifetime of ions in the upper lasing level (ULL) is longer than the lifetime of ions in the lower lasing level (LLL) then pumping of the laser medium to populate the ULL by excitation of ions from their ground state, perhaps via a level above the ULL, can be employed to maintain a population inversion between the ULL and LLL to allow lasing action to proceed. If, however, the lifetime of the ULL is shorter than the LLL, the lasing transition is known as self-terminating because the build up of ions in the LLL destroys the population inversion between the ULL and LLL required for lasing. Consequently such self-terminating lasers normally only operate in pulsed form, the LLL being given time to empty between pumping pulses.

The applicant's published application WO 89/11744 discloses a fluoro-zirconate optical fibre laser and amplifier in which cw operation of the normally self-terminating transition $^4I_{11/2}$ to $^4I_{13/2}$ is achieved by applying excitation energy to elevate ions from the lower lasing level to maintain a population inversion between the upper and lower lasing levels during lasing.

This use of excited state absorption (ESA) to provide the means of maintaining a population inversion to produce cw lasing eliminates the need to use high dopant concentrations necessary to obtain up-conversion from the LLL by ion-ion energy transfer. Instead, low dopant concentrations can be employed pumped highly efficiently by a laser for example. This is particularly the case if the laser medium comprises a doped optical fibre as the waveguiding properties of the fibre means high power densities can be maintained over large interaction lengths. This is also thermally efficient as the fibre core has a high surface-to-volume ratio.

This arrangement requires the pump means also

to provide pump energy at a wavelength and with an intensity sufficient to excite ions from the ground state to the ULL, perhaps via a more energetic level.

With the energy levels of some ions in a particular host, as discussed in the above referenced application, the wavelength and intensity of the pump excitation energy which elevates ions from the LLL can be chosen so that it also coincides with the energy difference between the ground state and an energy level, perhaps the ULL itself, which results in populating the ULL. This provides a much simplified arrangement in that a single wavelength source can be used to pump the ions to the ULL and to depopulate the LLL to prevent saturation. This coincidence of energy levels is not always present, however.

According to the present invention an optical amplifier comprises:

a medium incorporating lasing ions having an upper and a lower lasing level each above the ground state levels of the ions, which upper and lower lasing levels form a normally self-terminating laser transition; and

a pumping means for applying excitation energy of a suitable wavelength and intensity to elevate ions from the lower lasing level to maintain a population inversion between the upper and lower lasing levels;

CHARACTERISED IN THAT

the wavelength and intensity of the excitation energy is also suitable to elevate ions from the ground state levels to the upper lasing level by exciting ions both from the ground state levels to a first energy level and from the first energy level to a second energy level by excited state absorption.

The present invention provides a pumping scheme in which the simple arrangement of a single pump source can be used to provide, simultaneously, depopulation of the lower lasing level and population of the upper lasing level of a dopant ion in which the upper lasing level is at an energy greater than an energy level that can be directly populated from the ion's ground states by absorption of a single photon of the pump signal.

This scheme is equally applicable to lasers employing such amplifiers as a gain medium.

The laser or amplifier may be based on a fluoro-zirconate single mode optical fibre doped with Er^{3+} pumped at around 800 nm. This provides lasing or gain at around 850 nm from the $^4S_{3/2}$ to $^4I_{13/2}$ transition.

It should be appreciated that the pumping scheme of the present invention is applicable generally to dopant ions having suitable energy levels in a given host and is not restricted to any particular combination of host and dopant ion. It may also find application to bulk optic devices or other waveguide such as planar waveguides.

The present invention will now be described, by

way of example only, the reference for the accompanying drawings of which

Figure 1 is an energy level diagram for erbium in a ZBLAN optical fibre showing the relevant laser, fluorescence, and ESA transitions;

Figure 2 is a schematic diagram of a laser according to the present invention;

Figure 3 is a graph showing the laser characteristic of the laser of Figure 2;

Figure 4 is a graph of the excitation spectrum for the laser as Figure 2;

Figure 5 is a schematic diagram of an amplifier according to the present invention; and

Figure 6 is a graph of the evolution of gain in the amplifier of Figure 5.

Referring to Figure 1 there is shown the energy level diagram (without an indication of the broadened nature of the bands) of trivalent erbium in a fluoro-zirconate host. The laser to be described with reference to Figure 2 utilises the ($^4S_{3/2}$ to $^4I_{13/2}$) transition at around 850 nm wavelength. The lower lasing level $^4I_{13/2}$ has a lifetime of about 11 ms which normally makes this lasing transition self-terminating.

Pumping at 801 nm provides depopulation of the $^4I_{13/2}$ level by ESA to the $^2H_{11/2}$ level as well as population of the $^4S_{3/2}$ level by a two stage process, namely excitation to the $^4I_{9/2}$ level from the ground state $^4I_{15/2}$ level followed by ESA to the $^2H_{9/2}$ level.

The pumping scheme provides population of the $^4S_{3/2}$ level even though it is at a higher energy than the $^4I_{9/2}$ level, the highest energy level that can be directly populated from the ground state level by pumping at this wavelength.

The laser of Figure 2 comprises an experimental arrangement to determine the operating characteristics of an erbium doped, ZBLAN fibre 2 laser pumped according to the scheme of the present invention. The laser 2 is a 3 metre length of ZBLAN fibre, doped with 500 ppm/wt of erbium in a Fabry-Perot cavity with a 93% reflecting mirror 4 at one end and a cleaved fibre end 6 at the other, giving about 4% reflectivity. The fibre had a V-value of 4.5 at the pump wavelength. An 8% beamsplitter 8 at the input allowed extraction of a fixed proportion of the lasing light from which the output power could be determined. Almost all of the pump energy coupled into the fibre from a Ti:sapphire pumping laser 10 was absorbed. The output from the laser 10 passing to the fibre 2 via the beamsplitter 8 was coupled to the fibre 2 by means of a lens 12.

The remnant pump light, the lasing light and any spontaneous emission were separated using a blazed grating 14 at the output, and the optical power at the lasing and pump wavelengths was measured in a single order by a pair of detectors 16 and 18, respectively. The output power of the laser was then calibrated knowing the losses of the bulk optics and the beamsplitter ratio.

Other pump sources may be used to provide the

necessary optical pump power at about 800 nm for such an Er^{3+} doped ZBLAN fibre laser, in particular a semiconductor laser.

Figure 3 shows the lasing characteristic of the laser of Figure 2 when the pump laser 10 was tuned to 801 nm. The lasing threshold is high because of the low Q of the cavity, but the slope efficiency is also high at 38%. This is surprisingly efficient for a multi-photon excitation process.

Figure 4 plots the variation of the relative output power of the laser against the pump wavelength for a constant launched pump power of 396 mW (approx. threshold). The excitation spectrum has a width at the half-power points of 9 nm. This tuning curve follows the bleaching of the ground state transition. The ESA absorption process is therefore strong close to the peak of the ground-state absorption. Detuning the pump laser 10 to 792 nm allowed the population of the $^4I_{11/2}$ level to build up to the extent that lasing on the 3-level transition ($^4I_{11/2}$ to $^4I_{15/2}$) at 980 nm occurred.

Figure 5 shows schematically an experimental arrangement used to verify the amplification properties of the device in which 3 metre length of ZBLAN fibre 20 doped with 500 ppm/wt of erbium has reflection suppressed fibre ends 22 and 24. A pump laser 26 provides optical pump power at 801 nm which is coupled into the fibre and 22 via a dichroic beam splitter 28 and lens 30. A signal source at 850 nm is also introduced into end 22 of the fibre 20 via the beamsplitter 28 and lens 30. The power of the amplified 850 nm signal exiting fibre end 24 is measured by a detector 32 onto which the signal is focused by lens 34.

Figure 6 shows the evolution of gain at 850 nm with pump power at 801 nm in the device of Figure 5. The Q of the cavity of Figure 2 would require a single pass gain to reach a threshold of 7 dB, requiring 200 mW of pump power. This is confirmed from the lasing characteristic of Figure 3.

Claims

1. An optical amplifier comprising:

a medium (20) incorporating lasing ions having an upper and a lower lasing level each above the ground state levels of the ions, which upper and lower lasing levels form a normally self-terminating laser transition; and

a pumping means (26) for applying excitation energy of a suitable wavelength and intensity to elevate ions from the lower lasing level to maintain a population inversion between the upper and lower lasing levels;

CHARACTERISED IN THAT

the wavelength and intensity of the excitation energy is also suitable to elevate ions from the ground state levels to the upper lasing level by exciting ions both from the ground state levels



way of example only, the reference for the accompanying drawings of which

Figure 1 is an energy level diagram for erbium in a ZBLAN optical fibre showing the relevant laser, fluorescence, and ESA transitions;

Figure 2 is a schematic diagram of a laser according to the present invention;

Figure 3 is a graph showing the laser characteristic of the laser of Figure 2;

Figure 4 is a graph of the excitation spectrum for the laser as Figure 2;

Figure 5 is a schematic diagram of an amplifier according to the present invention; and

Figure 6 is a graph of the evolution of gain in the amplifier of Figure 5.

Referring to Figure 1 there is shown the energy level diagram (without an indication of the broadened nature of the bands) of trivalent erbium in a fluoro-zirconate host. The laser to be described with reference to Figure 2 utilises the ($^4S_{3/2}$ to $^4I_{13/2}$) transition at around 850 nm wavelength. The lower lasing level $^4I_{13/2}$ has a lifetime of about 11 ms which normally makes this lasing transition self-terminating.

Pumping at 801 nm provides depopulation of the $^4I_{13/2}$ level by ESA to the $^2H_{11/2}$ level as well as population of the $^4S_{3/2}$ level by a two stage process, namely excitation to the $^4I_{9/2}$ level from the ground state $^4I_{15/2}$ level followed by ESA to the $^2H_{9/2}$ level.

The pumping scheme provides population of the $^4S_{3/2}$ level even though it is at a higher energy than the $^4I_{9/2}$ level, the highest energy level that can be directly populated from the ground state level by pumping at this wavelength.

The laser of Figure 2 comprises an experimental arrangement to determine the operating characteristics of an erbium doped, ZBLAN fibre 2 laser pumped according to the scheme of the present invention. The laser 2 is a 3 metre length of ZBLAN fibre, doped with 500 ppm/wt of erbium in a Fabry-Perot cavity with a 93% reflecting mirror 4 at one end and a cleaved fibre end 6 at the other, giving about 4% reflectivity. The fibre had a V-value of 4.5 at the pump wavelength. An 8% beamsplitter 8 at the input allowed extraction of a fixed proportion of the lasing light from which the output power could be determined. Almost all of the pump energy coupled into the fibre from a Ti:sapphire pumping laser 10 was absorbed. The output from the laser 10 passing to the fibre 2 via the beamsplitter 8 was coupled to the fibre 2 by means of a lens 12.

The remnant pump light, the lasing light and any spontaneous emission were separated using a blazed grating 14 at the output, and the optical power at the lasing and pump wavelengths was measured in a single order by a pair of detectors 16 and 18, respectively. The output power of the laser was then calibrated knowing the losses of the bulk optics and the beamsplitter ratio.

Other pump sources may be used to provide the

necessary optical pump power at about 800 nm for such an Er^{3+} doped ZBLAN fibre laser, in particular a semiconductor laser.

Figure 3 shows the lasing characteristic of the laser of Figure 2 when the pump laser 10 was tuned to 801 nm. The lasing threshold is high because of the low Q of the cavity, but the slope efficiency is also high at 38%. This is surprisingly efficient for a multi-photon excitation process.

Figure 4 plots the variation of the relative output power of the laser against the pump wavelength for a constant launched pump power of 396 mW (approx. threshold). The excitation spectrum has a width at the half-power points of 9 nm. This tuning curve follows the bleaching of the ground state transition. The ESA absorption process is therefore strong close to the peak of the ground-state absorption. Detuning the pump laser 10 to 792 nm allowed the population of the $^4I_{11/2}$ level to build up to the extent that lasing on the 3-level transition ($^4I_{11/2}$ to $^4I_{15/2}$) at 980 nm occurred.

Figure 5 shows schematically an experimental arrangement used to verify the amplification properties of the device in which 3 metre length of ZBLAN fibre 20 doped with 500 ppm/wt of erbium has reflection suppressed fibre ends 22 and 24. A pump laser 26 provides optical pump power at 801 nm which is coupled into the fibre and 22 via a dichroic beam splitter 28 and lens 30. A signal source at 850 nm is also introduced into end 22 of the fibre 20 via the beamsplitter 28 and lens 30. The power of the amplified 850 nm signal exiting fibre end 24 is measured by a detector 32 onto which the signal is focused by lens 34.

Figure 6 shows the evolution of gain at 850 nm with pump power at 801 nm in the device of Figure 5. The Q of the cavity of Figure 2 would require a single pass gain to reach a threshold of 7 dB, requiring 200 mW of pump power. This is confirmed from the lasing characteristic of Figure 3.

Claims

1. An optical amplifier comprising:
 - a medium (20) incorporating lasing ions having an upper and a lower lasing level each above the ground state levels of the ions, which upper and lower lasing levels form a normally self-terminating laser transition; and
 - a pumping means (26) for applying excitation energy of a suitable wavelength and intensity to elevate ions from the lower lasing level to maintain a population inversion between the upper and lower lasing levels;

CHARACTERISED IN THAT

the wavelength and intensity of the excitation energy is also suitable to elevate ions from the ground state levels to the upper lasing level by exciting ions both from the ground state levels



- to a first energy level and from the first energy level to a second energy level by excited state absorption.
2. An amplifier as claimed in claim 1 in which the medium is an optical fibre waveguide.
 3. An amplifier as claimed in claim 2 in which the waveguide is of a fluoro-zirconate glass and the dopant is Er^{3+} .
 4. An amplifier as claimed in claim 2 in which the waveguide is a ZBLAN fibre doped with approximately 500 ppm/wt Er^{3+} .
 5. An amplifier as claimed in claim 3 or 4 in which the pump wavelength is about 801 nm.
 6. An amplifier as claimed in any preceding claim in which the pumping means is a semiconductor laser.
 7. A laser comprising:
 - a resonant cavity (2,4,6) including a medium (2) incorporating lasing ions having an upper and a lower lasing level each above the ground state levels of the ions, which upper and lower lasing levels form a normally self-terminating laser transition; and
 - a pumping means (10) for applying excitation energy of a suitable wavelength and intensity to elevate ions from the lower lasing level to maintain a population inversion between the upper and lower lasing levels;

CHARACTERISED IN THAT

the wavelength and intensity of the excitation energy is also suitable to elevate ions from the ground state levels to the upper lasing level by exciting ions both from the ground state levels to a first energy level and from the first energy level to a second energy level by excited state absorption.
 8. A laser as claimed in claim 7 in which the medium is an optical fibre waveguide (2).
 9. A laser as claimed in claim 8 in which the waveguide (2) is of a fluoro-zirconate glass and the dopant is Er^{3+} .
 10. A laser as claimed in claim 9 in which the waveguide is a ZBLAN fibre doped with approximately 500 ppm/wt Er^{3+} .
 11. A laser as claimed in claim 9 or 10 in which the pump wavelength is about 801 nm.
 12. A laser as claimed in any preceding claim in which the pumping means (10) is a semiconductor laser.
 13. A method of amplifying an optical signal, the method including the step of:
 - providing optical energy to optically pump a medium incorporating lasing ions having an upper and a lower lasing level, each level being above the ground state levels of the ions, which upper and lower lasing levels form a normally self-terminating laser transition, the pump energy being of suitable wavelength and intensity both to elevate ions from the lower lasing level to maintain a population inversion between the upper and lower lasing levels, and to elevate ions from the ground state levels to the upper lasing level by exciting ions from the ground state levels to a first energy level and from the first energy level to a second energy level by excited state absorption.
 14. A method of producing laser emission, the method including the step of providing optical energy to optically pump lasing ions of a medium in a resonant cavity, the lasing ions having an upper and a lower lasing level each above the ground state levels of the ions, which upper and lower lasing levels form a normally self-terminating laser transition, the pump energy being of suitable wavelength and intensity both to elevate ions from the lower lasing level to maintain a population inversion between the upper and lower lasing levels, and to elevate ions from the ground state levels to the upper lasing level by exciting ions from the ground state levels to a first energy level and from the first energy level to a second energy level by excited state absorption.
 15. A method as in claim 13 or claim 14, in which the medium is an optical fibre waveguide.
 16. A method as in claim 15, in which the waveguide comprises a fluorozirconate glass doped with Er^{3+} .
 17. A method as in claim 16, in which the waveguide is a ZBLAN fibre doped with approximately 500ppm/wt Er^{3+} .
 18. A method as in either one of claims 16 to 17, in which the wavelength of the optical pump energy is about 800nm.
 19. A method as in any one of claims 13 to 18, wherein the optical pump energy is provided by a semiconductor laser.



Patentansprüche

1. Optischer Verstärker mit
einem Medium (20), das laseraktive Ionen ent-
hält, die ein oberes und ein unteres, jeweils ober-
halb der Grundzustandsniveaus der Ionen lie-
gendes, Laserniveau haben, wobei das obere
und das untere Laserniveau einen normalerweise
selbstlöschenden Laserübergang bilden; und
einer Pumpvorrichtung (26) zur Einstrahlung von
Anregungsenergie geeigneter Wellenlänge und
Intensität, so daß Ionen aus dem unteren Laser-
niveau angehoben werden und eine Besetzungs-
umkehr zwischen dem oberen und dem unteren
Laserniveau aufrechterhalten wird,
dadurch gekennzeichnet, daß
die Wellenlänge und Intensität der Anregungs-
energie auch dazu geeignet sind, Ionen aus den
Grundzustandsniveaus in das obere Laserni-
veau anzuheben, indem Ionen sowohl aus den
Grundzustandsniveaus in ein erstes Energieni-
veau als auch durch Absorption im angeregten
Zustand aus dem ersten Energieniveau in ein
zweites Energieniveau angeregt werden.
2. Verstärker nach Anspruch 1, bei dem das Medi-
um ein Lichtwellenleiter ist.
3. Verstärker nach Anspruch 2, bei dem der Wellen-
leiter aus einem Fluorzirkonatglas besteht und
der Dotierstoff Er^{3+} ist.
4. Verstärker nach Anspruch 2, bei dem der Wellen-
leiter eine ZBLAN-Faser ist, die mit einem Ge-
wichtsanteil von ungefähr 500 ppm mit Er^{3+} do-
tiert ist.
5. Verstärker nach Anspruch 3 oder 4, bei dem die
Pumpwellenlänge ungefähr 801 nm beträgt.
6. Verstärker nach einem der vorangehenden An-
sprüche, bei dem die Pumpvorrichtung ein Halb-
leiterlaser ist.
7. Laser mit
einem Resonanzhohlraum (2, 4, 6), der ein Medi-
um (2) enthält, das laseraktive Ionen enthält, die
ein oberes und ein unteres, jeweils oberhalb der
Grundzustandsniveaus der Ionen liegendes, La-
serniveau haben, wobei das obere und das untere
Laserniveau einen normalerweise selbstlösch-
enden Laserübergang bilden; und
einer Pumpvorrichtung (10) zum Ausstrahlen von
Anregungsenergie geeigneter Wellenlänge und
Intensität, so daß Ionen aus dem unteren Laser-
niveau angehoben werden und eine Besetzungs-
umkehr zwischen dem oberen und dem unteren
Laserniveau aufrechterhalten wird,
dadurch gekennzeichnet, daß
die Wellenlänge und Intensität der Anregungs-
energie auch dazu geeignet sind, Ionen aus den
Grundzustandsniveaus in das obere Laserni-
veau anzuheben, indem Ionen sowohl aus den
Grundzustandsniveaus in ein erstes Energieni-
veau als auch durch Absorption im angeregten
Zustand aus dem ersten Energieniveau in ein
zweites Energieniveau angeregt werden.
8. Laser nach Anspruch 7, bei dem das Medium ein
Lichtwellenleiter (2) ist.
9. Laser nach Anspruch 8, bei dem der Wellenleiter
(2) aus einem Fluorzirkonatglas besteht und der
Dotierstoff Er^{3+} ist.
10. Laser nach Anspruch 9, bei dem der Wellenleiter
eine mit einem Gewichtsanteil von ungefähr 500
ppm mit Er^{3+} dotierte ZBLAN-Faser ist.
11. Laser nach Anspruch 9 oder 10, bei dem die
Pumpwellenlänge ungefähr 801 nm beträgt.
12. Laser nach einem der vorangehenden Ansprü-
che, bei dem die Pumpvorrichtung (10) ein Halb-
leiterlaser ist.
13. Verfahren zum Verstärken eines optischen Si-
gnals, wobei bei dem Verfahren
optische Energie zur Verfügung gestellt wird, um
ein Medium optisch zu pumpen, das laseraktive
Ionen mit einem oberen und einem unteren La-
serniveau enthält, von denen sich jedes Niveau
oberhalb der Grundzustandsniveaus der Ionen
befindet und die oberen und unteren Laserni-
veaus einen normalerweise selbstlöschenden
Laserübergang bilden, wobei die Wellenlänge
und Intensität der Pumpenergie dazu geeignet
sind, sowohl Ionen aus dem unteren Laserniveau
anzuheben, damit eine Besetzungsumkehr zwi-
schen dem oberen und dem unteren Laserniveau
aufrechterhalten wird, als auch Ionen aus den
Grundzustandsniveaus in das obere Laserni-
veau anzuheben, indem Ionen aus den Grundzu-
standsniveaus in ein erstes Energieniveau und
durch Absorption im angeregten Zustand aus
dem ersten Energieniveau in ein zweites Ener-
gieniveau angeregt werden.
14. Verfahren zum Erzeugen von Laseremission,
wobei bei dem Verfahren optische Energie zur
Verfügung gestellt wird, um laseraktive Ionen ei-
nes Mediums in einem Resonanzhohlraum op-
tisch zu pumpen, wobei die laseraktiven Ionen
ein oberes und ein unteres, jeweils oberhalb der
Grundzustandsniveaus der Ionen liegendes, La-
serniveau haben und das obere und das untere



Laserniveau einen normalerweise selbstlischenden Laserübergang bilden, und die Pumpenergie von geeigneter Wellenlänge und Intensität ist, so daß sowohl Ionen aus dem unteren Laserniveau angehoben werden und eine Besetzungsumkehr zwischen dem oberen und dem unteren Laserniveau aufrechterhalten wird als auch Ionen aus den Grundzustandsniveaus in das obere Laserniveau angehoben werden, indem Ionen aus den Grundzustandsniveaus in ein erstes Energieniveau und durch Absorption im angeregten Zustand aus dem ersten Energieniveau in ein zweites Energieniveau angeregt werden.

15. Verfahren nach Anspruch 13 oder Anspruch 14, bei dem das Medium ein Lichtwellenleiter ist.
16. Verfahren nach Anspruch 15, bei dem der Wellenleiter aus einem mit Er^{3+} dotierten Fluorzirconatglas besteht.
17. Verfahren nach Anspruch 16, bei dem der Wellenleiter eine mit einem Gewichtsanteil von ungefähr 500 ppm mit Er^{3+} dotierte ZBLAN-Faser ist.
18. Verfahren nach Anspruch 16 oder 17, bei dem die Wellenlänge der optischen Pumpenergie ungefähr 800 nm beträgt.
19. Verfahren nach einem der Ansprüche 13 bis 18, bei dem die optische Pumpenergie durch einen Halbleiterlaser zur Verfügung gestellt wird.

Revendications

1. Amplificateur optique comprenant :
un milieu (20) contenant des ions de production de l'effet laser possédant un niveau supérieur et un niveau inférieur de production de l'effet laser, qui sont situés chacun au-dessus des niveaux d'état de base des ions, lesquels niveaux supérieur et inférieur de production de l'effet laser forment une transition laser se terminant normalement de façon automatique; et
des moyens de pompage (26) servant à appliquer une énergie d'excitation possédant une longueur d'onde et une intensité appropriées pour élever les ions à partir du niveau inférieur de production de l'effet laser pour maintenir une inversion de population entre les niveaux supérieur et inférieur de production de l'effet laser, caractérisé en ce que
la longueur d'onde et l'intensité de l'énergie d'excitation conviennent également pour élever les ions des niveaux de l'état de base au niveau supérieur de production de l'effet laser par

excitation des ions à la fois à partir des niveaux de l'état de base jusqu'à un premier niveau d'énergie et à partir du premier niveau d'énergie jusqu'à un second niveau d'énergie par absorption de l'état excité.

2. Amplificateur selon la revendication 1, dans lequel le milieu est un guide d'ondes à fibre optique.
3. Amplificateur selon la revendication 2, dans lequel le guide d'ondes est un verre à base de fluorozirconate, et la substance dopante est du Er^{3+} .
4. Amplificateur selon la revendication 3 ou 4, dans lequel la longueur d'onde de pompage est égale à environ 800 nm.
5. Amplificateur selon l'une quelconque des revendications précédentes, dans lequel les moyens de pompage sont un laser à semiconducteurs.
6. Laser comprenant :
une cavité résonnante (2,4,6) comprenant un milieu (2) contenant des ions de production de l'effet laser possédant un niveau supérieur et un niveau inférieur de production de l'effet laser, qui sont situés chacun au-dessus des niveaux d'état de base des ions, lesquels niveaux supérieur et inférieur de production de l'effet laser forment une transition laser se terminant normalement de façon automatique; et
des moyens de pompage (10) servant à appliquer une énergie d'excitation possédant une longueur d'onde et une intensité appropriées pour élever les ions à partir du niveau inférieur de production de l'effet laser pour maintenir une inversion de population entre les niveaux supérieur et inférieur de production de l'effet laser, caractérisé en ce que
la longueur d'onde et l'intensité de l'énergie d'excitation conviennent également pour élever les ions des niveaux de l'état de base au niveau supérieur de production de l'effet laser par excitation des ions à la fois à partir des niveaux de l'état de base jusqu'à un premier niveau d'énergie et à partir du premier niveau d'énergie jusqu'à un second niveau d'énergie par absorption de l'état excité.
7. Laser selon la revendication 7, selon lequel le milieu est un guide d'ondes à fibre optique (2).
8. Laser selon la revendication 8, dans lequel le guide d'ondes (2) est un verre à base de fluoro-zirconate et la substance dopante est du Er^{3+} .
9. Laser selon la revendication 9, dans lequel le gui-



de d'ondes est une fibre ZBLAN dopée avec approximativement 500 ppm/poids de Er^{3+} .

10. Laser selon la revendication 9 ou 10, dans lequel la longueur d'onde de pompage est égale à environ 801 nm.

11. Laser selon l'une quelconque des revendications précédentes, dans lequel les moyens de pompage (10) sont un laser à semiconducteurs.

12. Procédé pour amplifier un signal optique, le procédé incluant l'étape consistant à :

appliquer une énergie optique pour réaliser le pompage optique d'un milieu contenant des ions laser possédant un niveau supérieur et un niveau inférieur de production de l'effet laser, chaque niveau étant situé au-dessus des niveaux des états de base des ions, lesquels niveaux supérieur et inférieur de production de l'effet laser forment une transition laser se terminant normalement de façon automatique, l'énergie de pompage possédant une longueur d'onde et une intensité appropriées à la fois pour élever les ions à partir du niveau inférieur de production de l'effet laser pour maintenir une inversion de population entre les niveaux supérieur et inférieur de production de l'effet laser, élever les ions à partir des niveaux d'état de base jusqu'au niveau supérieur de production de l'effet laser par excitation d'ions à partir des niveaux d'état de base jusqu'à un premier niveau d'énergie à partir du premier niveau d'énergie jusqu'à un second niveau d'énergie au moyen d'une absorption d'états excités.

13. Procédé de production d'émission laser, le procédé incluant l'étape consistant à appliquer une énergie optique pour réaliser le pompage optique d'ions de production de l'effet laser dans un milieu situé dans une cavité raisonnable, les ions de production de l'effet laser possédant le niveau supérieur et le niveau inférieur de production de l'effet laser, situés chacun au-dessus des niveaux d'états de base des ions, lesquels niveaux supérieur et inférieur de production de l'effet laser forment une transition laser s'arrêtant normalement de façon automatique, l'énergie de pompage possédant une longueur d'onde et une intensité appropriées à la fois pour élever les ions à partir du niveau inférieur de production de l'effet laser pour maintenir une inversion de population entre les niveaux supérieur et inférieur de production de l'effet laser, élever les ions à partir des niveaux d'état de base jusqu'au niveau supérieur de production de l'effet laser par excitation d'ions à partir des niveaux d'état de base jusqu'à un premier niveau d'énergie à partir du premier

niveau d'énergie jusqu'à un second niveau d'énergie au moyen d'une absorption d'états excités.

14. Procédé selon la revendication 13 ou 14, selon lequel le milieu est un guide d'ondes à fibre optique.

15. Procédé selon la revendication 15, selon lequel le guide d'ondes comprend un verre en fluorozirconate dopé par du Er^{3+} .

16. Procédé selon la revendication 16, selon lequel le guide d'ondes est une fibre ZBLAN dopée par environ 500 ppm/poids Er^{3+} .

17. Procédé selon l'une ou l'autre des revendications 16 à 17, selon lequel la longueur d'onde de l'énergie de pompage optique est égale à environ 800 nm.

18. Procédé selon l'une quelconque des revendications 13 à 18, dans lequel l'énergie de pompage optique est délivrée par un laser à semiconducteurs.