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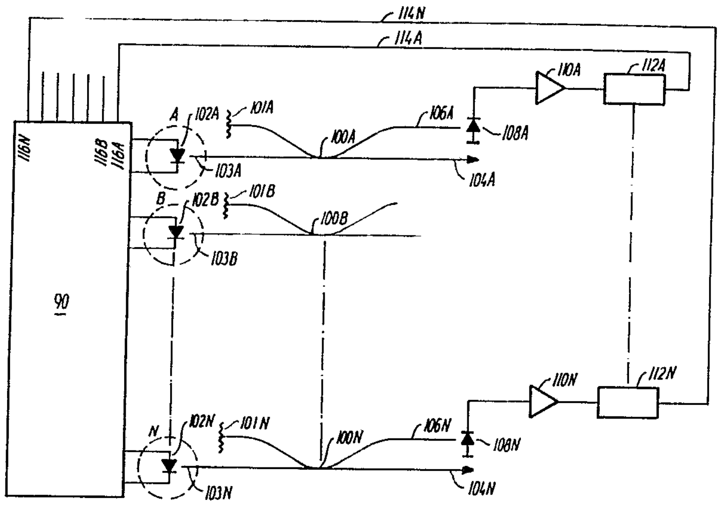
In English translation (filed in Danish).

(54) Title: AN OPTICAL FIBRE AMPLIFIER WITH COUPLING OF PUMP ENERGY FROM SEVERAL PUMP SOURCES



(57) Abstract

An optical fibre amplifier having one or more active fibres so coupled to an optical transmission line that each of the active fibres has at least one input for a pump signal. The active fibres are adapted to amplify an optical signal at a first wavelength at stimulated emission, when optical energy is added in the form of a pump signal at a second wavelength. The pump signals are provided by means of pump lasers adapted to emit energy at the second wavelength. The optical fibre amplifier has an optical combination network with a plurality of inputs coupled to respective pump lasers and adapted to receive energy from these. The outputs of the combination network are coupled to the pump signal inputs on the active fibres, said network being adapted to combine the optical energy added from the pump lasers so that the optical energy on each one of the outputs of the combination network originates from several pump lasers. Drop-out of a pump laser will cause the optical signal on several outputs on the combination network to be reduced, but complete drop-out of optical energy on an output is obviated.

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+ DESIGNATIONS OF "SU"

Any designation of "SU" has effect in the Russian Federation. It is not yet known whether any such designation has effect in other States of the former Soviet Union.

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An optical fibre amplifier with coupling of pump energy from several pump sources

The invention concerns an optical fibre amplifier, and in particular the part that concerns coupling of pump energy from a plurality of pump sources.

The occurrence of optical fibre amplifiers is expected to involve a tremendous development within optical communications networks, since an optical component has been made available which is capable of amplifying an optical signal in an optical transmission path without having to generate electronic signals en route. Such optical amplifiers thus find application within many branches of optical communications systems. Optical fibre amplifiers may e.g. be used in a fibre-optical ringnet accessed by a plurality of transmitter/receiver units, and it may be used for increasing the distance over which a receiver can receive and re-form a signal from a transmitter. Here, it may e.g. be used as an in-line amplifier, it being positioned at a great distance from both transmitter and receiver. It is also possible to use an optical amplifier as a pre-amplifier of a receiver. Alternatively, it may be used as a booster amplifier, i.e. the fibre amplifier amplifies the optical signal immediately after it is transmitted from the transmitter.

Optical fibre amplifiers are usually made by doping an optical fibre with rare earths, such as erbium, during the manufacturing process. Amplification takes place [illegible] addition of energy that excites electrons to a higher energy level. When stimulated with light energy from e.g. the arriving signal, the electrons will fall to a lower energy level, transmitting light at the frequency in question. This is analogous to the behaviour of a laser.

The active fibre is pumped optically with a plurality of pump lasers to provide the desired amplification. However, the reliability of these pump lasers is a problem since their life is limited considerably when providing maximum power. This is a problem in particular when using the active fibre in a booster amplifier, since particularly strong pumping is necessary here to obtain the required signal amplification so that the signal can be detected over great distances. If an active fibre is pumped by one laser, and this laser drops out, the fibre will absorb signal power instead of amplifying the signal. The concentration of active ions, e.g. erbium ions, in the active fibre determines both the amplification of an optical signal by optical pumping and the absorption of the same optical signal, absorption taking place in particular when optical pumping is missing. Similarly, the threshold value also depends upon the ion concentration, said threshold value being the pump energy amount to be added to the active fibre for this to contribute with amplification which corresponds precisely to the fibre absorption of signal energy. By pumping the active fibre with the threshold value energy amount, the fibre will have a resulting amplification which is precisely 0 dB, and it will thus not influence the signal level. When the pump power is reduced, the absorption of the signal is increased, entailing that optical systems with optical amplifiers are extremely sensitive to drop-out of just a single pump laser. Even if several active fibres are cascade-coupled in succession, and these fibres are simultaneously pumped bi-directionally, the amplification of the optical fibre amplifier, when just a single pump laser drops out, will be reduced to such a degree that system errors will occur.

The object of the invention is to provide a reliable optical fibre amplifier without the prior art sensitivity to drop-out of pump lasers.

This object is achieved as stated in the characterizing portion of claim 1. The advantage is that the pump signal from a laser is divided on a plurality of active fibres so that the signal from there just contributes with a fraction of the pump power to each fibre, so that even though missing contribution from a laser is still noticeable, the active fibre nevertheless continues to contribute actively to amplification of an optical signal.

An optical fibre amplifier may e.g. be pumped with pump energy with a variety of wavelengths, which may e.g. be those stated in claim 4. The advantage of pumping at two different wavelengths is that two pump sources can be coupled into a fibre, so that four pumps may be used for an active fibre.

As stated in claim 5, the combination network may consist of a fibre-optical network with fibre couplers, thereby minimizing the coupling losses.

When the optical amplifier is moreover provided with a compensation network, as stated in claim 7, suitable amplification may be maintained even if one or more pump lasers drops out.

The invention will be explained more fully below in connection with preferred embodiments and with reference to the drawing, in which

fig. 1 schematically shows where an optical fibre amplifier is useful,

fig. 2 schematically shows the structure of a fibre amplifier according to the prior art, fig. 3 schematically shows a preferred embodiment of the structure of an optical fibre amplifier according to the invention,

fig. 4 schematically shows an alternative embodiment of an optical fibre amplifier according to the invention, and

fig. 5 schematically shows an embodiment of compensation circuits for use in an optical fibre amplifier according to the invention.

Fig. 1a shows a transmitter 5 which transmits an optical signal to a receiver 9 through an optical transmission line 6. For the distance between the transmitter 5 and the receiver 9 to be increased, the transmitted signal must be amplified en route. This is done by coupling a fibre end suitably spaced from the transmitter 5 into an optical fibre amplifier 7, which amplifies the signal and passes the signal thus amplified back to the transmission line 6 and further on to the receiver 9. To limit the noise from the optical amplifier, an optical bandpass filter 8 is positioned before a receiver 9. An optical fibre amplifier used in this manner is usually called an in-line amplifier. Fig. 1b shows an optical fibre amplifier used as a pre-amplifier, it being used for amplifying the optical signal on the transmission line 6 prior to signal detection. Since, here too, the noise is amplified by the optical amplifier, a bandpass filter 8 is positioned before the receiver 9. Fig. 1c shows an optical fibre amplifier used as a booster amplifier, said fibre amplifier being thus connected to the output on the transmitter 5.

Fig. 2 shows the structure of an optical fibre amplifier according to the prior art, where an optical signal is introduced via an optical transmission line 13 and coupled into an active fibre. Such an active fibre 12 may e.g. be doped with erbium and have a length of typically 10-100 m. After amplification in an active fibre 12, an optical signal is again passed back to an optical transmission path 14. Analogous with the behaviour of a laser, amplification takes place by exciting electrons in an active medium to a higher energy level, from which the electrons can fall back to a lower energy level at stimulated emission, thereby transmitting light in a given wavelength range. This addition of energy is usually called pumping, and active pump sources 10 in the form of laser diodes are ordinarily used in optical fibre amplifiers. Energy from the pump sources 10 is coupled into the active fibre 3 through respective dichromatic couplers 11.

Fig. 3 shows an optical fibre network connecting four pump sources 20, 21, 22, 23 to four active fibres 30, 31, 32, 33, which are coupled in series (cascade coupling) and are adapted to receive an optical signal on an input 34, to amplify this signal and to apply the amplified signal on an output 35. Each of the pump sources 20, 23 emit optical power P, which will usually be the same for the four pump sources. This optical power will be marked by an index A, B, C, D below, so that the origin of the power will be visible from the expressions used. The output signal from the pump source 20 and the pump source 21, respectively, is passed to a fibre coupler 25 (3 dB coupler) designed so that there will be a signal with the power $(P_A + P_B)/2$ on each of the outputs of the fibre coupler. Correspondingly, a fibre coupler 26 divides the optical energy from the pump sources 22, 23, so that there will be an optical signal with the power $(P_C + P_D)/2$ on each of the outputs of the fibre coupler 26. Each of two additional fibre couplers 27, 28 receives a signal from respective outputs of the fibre couplers 25, 26, whereby the optical energy from each of the pump sources 20-23 is combined so that there will be an optical signal with the power $(P_A + P_B + P_C +$

P_D)/4 on each output of the fibre couplers 27, 28. Each of the four active fibres 30-33 will thus receive an optical signal combined so that the output signal from a pump source 20-23 is passed to several pump inputs. Drop-out of a pump source 20-23 will thus entail that approximately 25% less optical power will be added to each of the active fibres 30-33. This loss may be compensated by increasing the pump power of the other pump sources by 33%, as will be explained in connection with fig. 5.

Fig. 4 shows a corresponding configuration, where an optical signal on an input 52 is amplified in two active fibres 50, 51 and is passed to an output 53. Four pump sources 40, 41, 42, 43 emit optical power P like in the previous example. The pump power from the pump sources 40, 41 is passed to a fibre coupler 45 having a signal with the power (P_A + P_B)/2 on each of its outputs. Correspondingly, a fibre coupler 46 has an optical signal with the power (P_C + P_D)/2 on each of its outputs. The two active fibres 50, 51 are pumped bi-directionally, i.e. the active fibres 50, 51 are pumped from their respective ends with a signal from each of the fibre couplers 45, 46. Thus, each fibre receives an optical signal having the power (P_A + P_B + P_C + P_D)/2. It is noted that each active fibre 50, 51 receives a pump signal which is twice as great as in the above-mentioned example.

Fig. 5 shows a drive circuit 90 which drives a plurality of laser diodes 102 A-N which are coupled to respective fibre ends 103 A-N. From there, the optical pump energy from respective laser diodes 102 A-N is passed to an optical combination network, such as the one shown in fig. 3 or 4, through a fibre section 104 A-N. The fibre 103 A-N is moreover coupled to an optical fibre coupler 100 A-N, which may e.g. be designed so that 1% of the energy on the optical fibre is passed through the fibre branch 106 A-N, while the rest of the optical energy is passed through the fibre branch 104 A-N. Owing to reflection, the fibre couplers 100 A-N are terminated in respective adaptations 101 A-N. The optical energy on the fibre 106 A-N is passed to respective photodiodes 108 A-N, where the optical signal is converted to an electrical signal passed to respective amplifiers 110 A-N and from there further on to respective detection circuits 112 A-N. These detection circuits 112 A-N apply a signal on the output which is passed through respective wires 114 A-N to respective inputs 116 A-N on the drive circuit.

The detection circuit 112 A-N detect whether the photodiodes 108 A-N receive an optical signal and thus whether the laser diodes 102 A-N apply a signal. If one of the laser diodes 102 A-N drops out and thus stops emitting optical energy, this can be detected by the detection circuit 112 A-N which applies a signal to the drive circuit 90 in response to this, said signal indicating whether the laser diode 102 A-N associated with the individual detection circuit 112 A-N operates correctly or is faulty. Usually, the laser diodes 102 A-N do not emit maximum power, but is driven at a smaller load owing to reliability and life. In response to a received error message from one of the detection circuits 112 A-N, the drive circuit 90 can increase the output power of the remaining laser diodes 102 A-N, thereby fully compensating for the missing power from one or more laser diodes which have dropped out. Referring to the configuration shown in fig. 3, drop out of a single laser diode may be compensated by increasing the pump power of the other pump sources by 33%. The drive circuit 90 may simultaneously be designed to apply a signal to a central monitoring unit, which will then be informed that there is a faulty laser diode in the optical amplifier, and that this laser diode should be replaced at a later time.

The principle of combining an optical pump power in a combination network before the pump signals are applied to a variety of optical fibres can be developed in simple manner. If, e.g. amplification of an optical signal is needed on a not very accessible locality, the number of pump sources may expediently be increased to e.g. 16. The pump signals are combined and passed to a plurality of active fibres, of which there may e.g. be 4. Pump power corresponding to $(P_1 + P_2 + \ldots + P_{16})/4$ may then be added to the fibres. The output power from each individual pump source is then regulated so that the optical amplifier is dimensioned to be able to still provide an acceptable amplification, even though a number of pump sources drop out en route (e.g. 5). The amplifier may thus be dimensioned so that it is attempted to limit the output power of the individual pump sources in the same manner as in the prior art, thereby increasing their life while making the system immune to the possibility that a not insignificant number of the pump sources eventually become defective.

The invention has been explained with reference to a fibre optical network consisting of optical fibres having fibre couplers of the 2:2 type, i.e. couplers with two inputs and two outputs. Nothing prevents the invention from being performed with other coupling configurations, such as 4:4 couplers, or configurations where the number of inputs and outputs is not the same.

It will also be possible to use various pump lasers which e.g. emit light of different wavelengths, e.g. at 1480 nm, 980 nm and at 820 nm. When using wavelength ranges far from each other, the active fibres may be pumped to various atomic energy levels.

P a t e n t   C l a i m s :

1. An optical fibre amplifier having one or more active fibres coupled to an optical transmission line such that each such active fibre has at least one input for a pump signal, said active fibre being of the type adapted to amplify an optical signal at a first wavelength at stimulated emission, through addition of optical energy in the form of a so-called pump signal at a second wavelength, the configuration comprising a plurality of pump lasers adapted to transmit energy at the second wavelength, c h a r a c t e r i z e d in that it has an optical combination network comprising a plurality of inputs coupled to respective pump lasers and adapted to receive energy from these, and a plurality of outputs coupled to the pump signal inputs on the active fibres, said network comprising means for combining the energy received on the inputs such that the signal on an output represents energy from several inputs.

2. An optical fibre amplifier according to claim 1, c h a r a c t e r i z e d by including at least one pump laser adapted to transmit energy at one wavelength, and moreover including at least one further pump laser adapted to emit energy at a wavelength different from the first wavelength.

3. An optical fibre amplifier according to claim 1 or 2, c h a r a c t e r i z e d by including at least one pump laser adapted to emit energy at a first polarization state, and including at least one further pump laser adapted to emit energy at a second polarization state.

4. An optical fibre amplifier according to claim 2, c h a r a c t e r i z e d by including at least one pump

laser adapted to emit energy at a wavelength about λ = 1480 nm, and including at least one further pump laser adapted to emit energy at a wavelength λ = 820 nm or λ = 980 nm.

5. An optical fibre amplifier according to claim 1, characterized in that the optical combination network is a fibre-optical network.

6. An optical fibre amplifier according to claim 5, characterized in that the means for combining the energy from the pump lasers comprise fibre couplers.

7. An optical fibre amplifier according to claims 1-6, characterized by including means for detecting an output signal from respective pump lasers, and including means for determining the level of the output signal and for regulating the output signal of respective pump lasers in response thereto.

8. An optical fibre amplifier according to claim 7, characterized in that the detection means detect the presence of an optical signal from respective pump lasers, and that the output signal level of the other pump lasers is increased if said signal is below a given threshold value.

AMENDED CLAIMS

[received by the International Bureau on 11 February 1992 (11.02.92); original claims 1-8 replaced by amended claims (2 pages)]

1. An optical fibre amplifier having one or more active fibres (30-33; 50, 51) coupled to an optical transmission line (34, 35; 52, 53) such that each such fibre (30-33; 50, 51) has at least one input for a pump signal, said active fibre being of the type adapted to amplify an optical signal at a first wavelength at stimulated emission, through addition of optical energy in the form of a so-called pump signal at a second wavelength, the configuration comprising a plurality of pump lasers (20-23; 40-43) adapted to transmit energy at the second wavelength, the coupling between pump lasers (20-23; 40-43) and the inputs for the pump signals being established via an optical combination network with a plurality of inputs which are coupled to respective pump lasers (20-23; 40-43) and receive energy from these, and a plurality of inputs coupled to respective pump signal inputs on the active fibres (30-33; 50, 51), said network having means (25-28; 45, 46) for combining the energy received on the inputs, c h a r a c t e r i z e d in that the energy combining means (25-28; 45, 46) of the combination network split up the pump energy received from each individual pump laser (20-23; 40-43), and that the energy combining means (25-28; 45, 46) combine the split-up pump energy to respective pump signal inputs, pump energy from each pump laser (20-23; 40-43) being thereby distributed to two or more pump signal inputs on said active fibres (30-33; 50, 51).

2. An optical fibre amplifier according to claim 1, c h a r a c t e r i z e d by including at least one pump laser (20-23; 40-43) adapted to transmit energy at one wavelength, and moreover including at least one further pump laser (20-23; 40-43) adapted to emit energy at a wavelength different from the first wavelength.

3. An optical fibre amplifier according to claim 1 or 2, c h a r a c t e r i z e d by including at least one pump laser (20-23; 40-43) adapted to emit energy at a first polarization state, and including at least one further pump laser (20-23; 40-43) adapted to emit energy at a second polarization state.

4. An optical fibre amplifier according to claim 2, c h a r a c t e r i z e d by including at least one pump laser (20-23; 40-43) adapted to emit energy at a wavelength about λ = 1480 nm, and including at least one further pump laser (20-23; 40-43) adapted to emit energy at a wavelength λ = 820 nm or λ = 980 nm.

5. An optical fibre amplifier according to claim 1, c h a r a c t e r i z e d in that the optical combination network is a fibre-optical network.

6. An optical fibre amplifier according to claim 5, c h a r a c t e r i z e d in that the means (25-28; 45, 46) for combining the energy from the pump lasers (20-23; 40-43) comprise fibre couplers.

7. An optical fibre amplifier according to claims 1-6, c h a r a c t e r i z e d by including means (108A-N) for detecting an output signal from respective pump lasers (102A-N), and including means (112A-N) for determining the level of the output signal and for regulating the output signal of respective pump lasers (102A-N) in response thereto.

8. An optical fibre amplifier according to claim 7, c h a r a c t e r i z e d in that the detection means (112A-N) detect the presence of an optical signal from respective pump lasers (102A-N), and that the output signal level of the other pump lasers is increased if said signal is below a given threshold value.

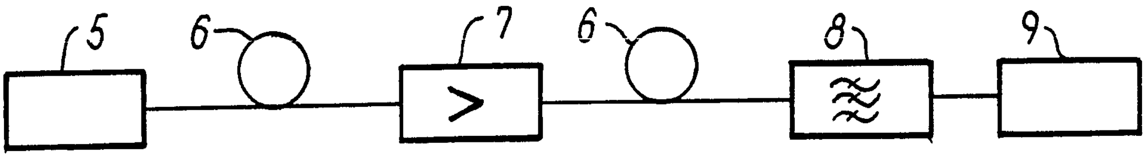

FIG. 1a

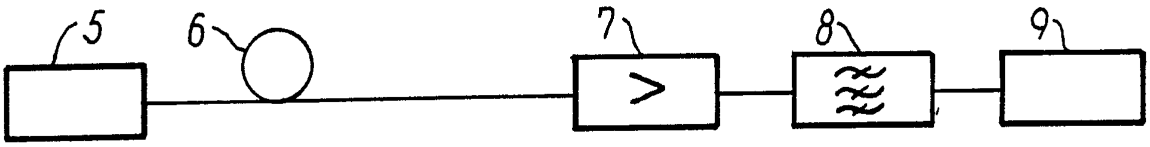

FIG. 1b

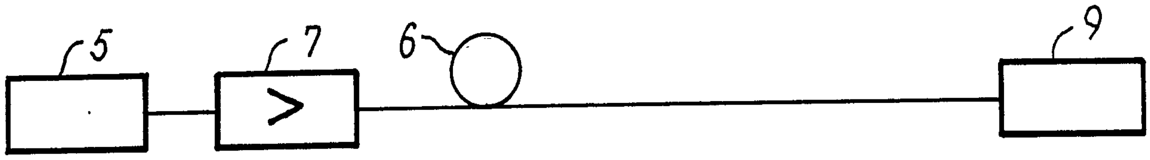

FIG. 1c

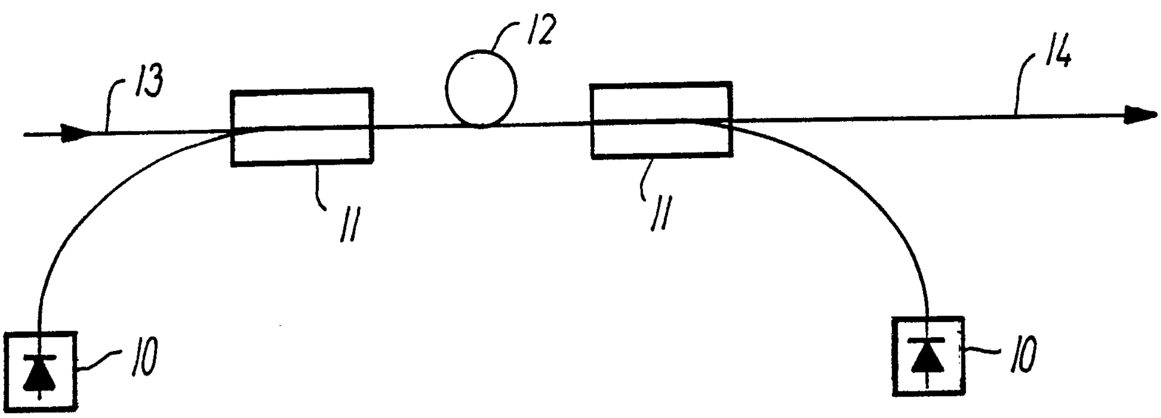

FIG. 2

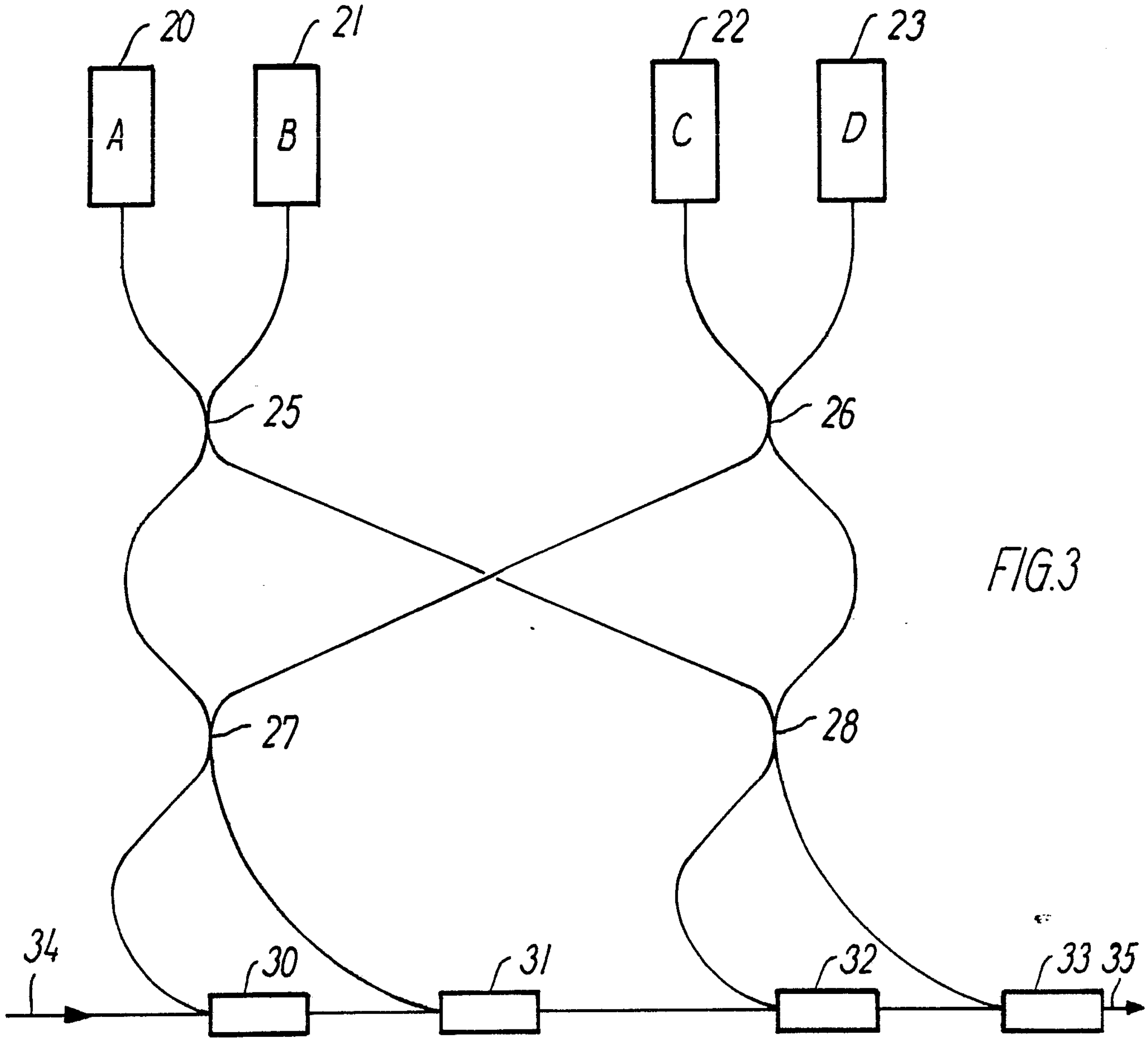
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FIG.3

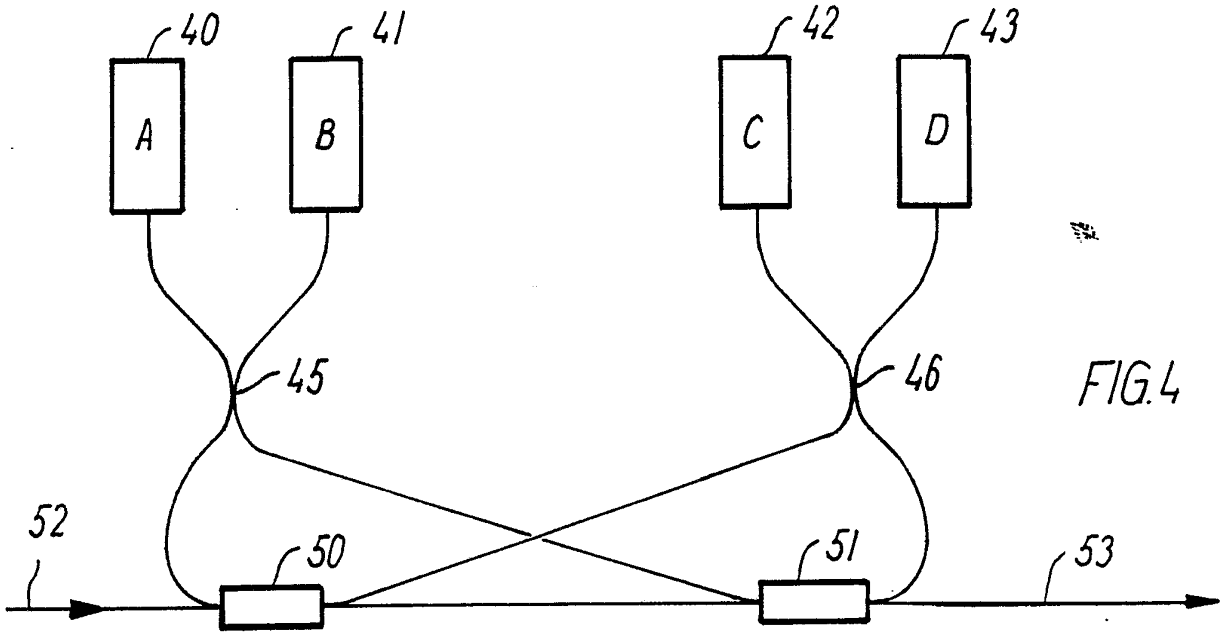
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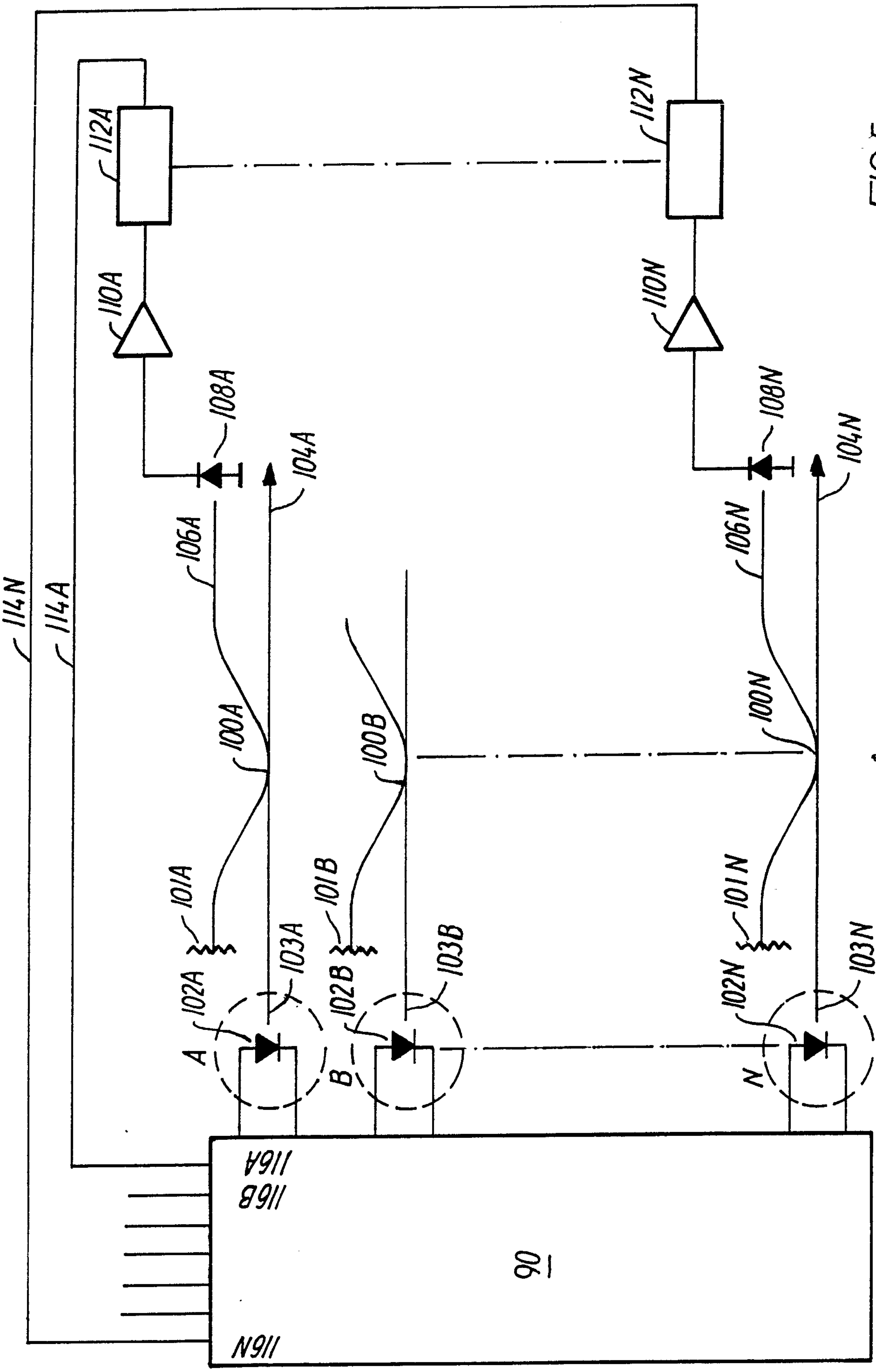
FIG.4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116A
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FIG.5

INTERNATIONAL SEARCH REPORT

International Application No PCT/DK 91/00267

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: H 04 B 10/12, H 01 S 3/07

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	H 04 B, H 01 S

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
Y	EP, A1, 0408394 (BRITISH TELECOMMUNICATIONS PUBLIC LIMITED COMPANY) 16 January 1991, see column 5, line 58 - column 6, line 9	1
A	--	2-8
Y	EP, A2, 0339840 (AMERICAN TELEPHONE AND TELEGRAPH COMPANY) 2 November 1989, see column 11, line 25 - line 40; figure 8 --	1
Y	EP, A2, 0215711 (INTERNATIONAL STANDARD ELECTRIC CORPORATION) 25 March 1987, see page 2, line 18 - line 20; page 5, line 10 - line 12; figure 2	1
A	--	2-8

* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
16th December 1991	1991 -12- 1 8
International Searching Authority	Signature of Authorized Officer
SWEDISH PATENT OFFICE	RUNE BENGTSSON

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	EP, A1, 0395277 (STC PLC) 31 October 1990, see the whole document -- --------	7-8

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.PCT/DK 91/00267

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 31/10/91
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A1- 0408394	91-01-16	AU-D- 6044490	91-02-06
		GB-A- 2236895	91-04-17
		WO-A- 91/01066	91-01-24
EP-A2- 0339840	89-11-02	JP-A- 2012986	90-01-17
		US-A- 4881790	89-11-21
EP-A2- 0215711	87-03-25	JP-A- 62061448	87-03-18
		US-A- 4775210	88-10-04
EP-A1- 0395277	90-10-31	GB-A- 2230912	90-10-31
		JP-A- 3062022	91-03-18