FORM 1

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

618095

Application for a Standard Patent or A Standard Patent of Addition

We, ALCATEL N.V. of Strawinskylaan 341 1077 XX Amsterdam, The Netherlands,

, hereby apply for the grant of a standard patent/patent of addition for an invention entitled

"OPTICAL COMMUNICATION SYSTEM"

which is described in the accompanying provisional/complete specification.

Details of basic application(s) –

Number of basic application P 38 19 445

Name of Convention country in which basic application was filed Germany

Date of basic application 8 June 1988

Our address for service is:

PATENT DEPARTMENT,
STANDARD TELEPHONES AND CABLES PTY. LIMITED,
252-280 BOTANY ROAD,
ALEXANDRIA, N.S.W. 2015.
AUSTRALIA.

Dated this Twentyfifth day of May 19 89

ALCATEL N.V.

BY: ....

Signature of Applicant

To: The Commissioner of Patents

FORM 8

COMMONWEALTH OF AUSTRALIA
PATENTS ACT 1952 - 1969

DECLARATION IN SUPPORT OF A CONVENTION APPLICATION FOR A PATENT OR A PATENT OF ADDITION

In support of the Convention application made for a patent ~~of addition~~ for an invention entitled

"OPTICAL COMMUNICATION SYSTEM"

I, BRIAN PATRICK O'CONNOR
of STANDARD TELEPHONES AND CABLES PTY. LIMITED, 252-280 Botany Road, Alexandria, 2015, N.S.W., Australia
do solemnly and sincerely declare as follows:-

1. I am authorised by ALCATEL N.V. the applicant for the patent ~~of addition~~ to make this declaration on its behalf.

2. The basic application as defined by Section 141 of the Act was/~~were~~ made in Germany

on 8 June 1988

by STANDARD ELEKTRIK LORENZ AG

3. KURT FUSSGANGER, of Konigsberger Strasse 1, 7148 Remseck 2, Germany, and HEINZ G. KRIMMEL, of Dieterlestrasse 66, 7000, Stuttgart 30, Germany

~~is~~/are the actual inventors of the invention, and the facts upon which the applicant is entitled to make the application are as follows:-

ALCATEL N.V. is the Assignee of STANDARD ELEKTRIK LORENZ AG who is the Assignee of THE SAID INVENTORS.

4. The basic application referred to in paragraph 2 of this Declaration was/~~were~~ the first application in a Convention country in respect of the invention the subject of the application.

Declared at Sydney this 25th day of May 19~~7~~89

ALCATEL N.V.

....
Signature of Declarant

To: The Commissioner of Patents.

(12) PATENT ABRIDGMENT (11) Document No. AU-B-35228/89
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OPTICAL COMMUNICATION SYSTEM

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(56) Prior Art Documents
AU 596451 79916/87 H04B 009/00
US 4637072
US 4910727

(57) Claim

1. An optical communication system for the transmission of an optical signal/s, comprising at least one first optical transmitter coupled to at least one first optical receiver by a transmission link comprising a main optical waveguide in which only the fundamental mode can propagate above a cut-off wavelength, the operating wavelength of said optical transmitter and said first optical receiver being of a predetermined value and below the said cut-off wavelength, said optical signal/s being transmitted in the fundamental mode wherein said transmission link contains sections of single mode optical waveguides to attenuate higher-order modes, respective sections being located at each end of said main optical waveguide and joined thereto at one end by a fusion splice, the other end being coupled to said optical transmitter/receiver via optical connector means.

3. A transmitting device for an optical communication system wherein an optical signal is transmitted over a single-mode first optical waveguide in the fundamental mode and at an operating wavelength lower than the cut-off wavelength of the said optical waveguide, said transmitting device including an optical transmitter having a section of second optical waveguide coupled thereto which is a single-mode optical waveguide at the operating wavelength, and wherein an optical connector means is inserted in said section, and that the free end of said section is designed to be joined to the first optical waveguide by a fusion splice.

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5. A receiving device for an optical communication system wherein an optical signal is transmitted over a single-mode first optical waveguide in the fundamental mode and at an operating wavelength lower than the cut-off wavelength of the optical waveguide, said receiving device including an optical receiver having a section of second optical waveguide coupled thereto which is a single-mode optical waveguide at the operating wavelength, and wherein an optical connector means is inserted in said section, and that one end of said section is coupled to the optical receiver, while the other free end is arranged to be joined to the first optical waveguide by a fusion splice.

618095

ORIGINAL

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952-1969

COMPLETE SPECIFICATION FOR THE INVENTION ENTITLED

"OPTICAL COMMUNICATION SYSTEM"

The following statement is a full description of this invention, including the best method of performing it known to us:-

This invention relates to an an optical communication system, for the transmission of an optical signal/s, comprising at least one first optical transmitter coupled to at least one first optical receiver by a transmission link comprising a main optical waveguide in which only the fundamental mode can propagate above a cut-off wavelength, the operating wavelength being below the cut-off wavelength, said optical signal/s being transmitted in the fundamental mode.

Such a system is described in SPIE Vol. 841 Fibre Optic Networks & Coherent Technology in Fibre Optic Systems II (1987), pages 116 to 123. This system uses low-cost optical transmitters and receivers with an operating wavelength of about 800 nm, and a single-mode optical waveguide which, however, is "single-mode" only above a cut-off wavelength of 1300 nm. Nevertheless it is ensured that transmission takes place only in the fundamental mode.

This is achieved, inter alia, by mode filters which attenuate the higher-order modes and are implemented as sections of optical waveguide, which are single-mode optical waveguides at the operating wavelength of the optical transmitters and receivers. The optical-waveguide section at the transmitting end has one end coupled to the optical transmitter, while its other end is connected either by a connector to the optical waveguide forming the transmission link or by a fusion splice to an optical waveguide jumper. The optical-waveguide section at the receiving end ("0.25 m 800 nm SM fibre") has one end connected by a fusion splice to the optical waveguide forming the transmission link, while the other end is not coupled directly to the receiver but spliced to a multimode pigtail coupled to the receiver. The article further states that at connectors and splices, the funamental mode LP_{01} may be partially converted to the next-higher-order mode group LP_{11}, and that as a result, undesired modal noise and undesired modal dispersion can occur. The only measure proposed in the article for reducing this modal noise and modal dispersion is to filter the higher-order LP_{11} mode group.

It is, therefore, the object of the invention to provide a system of the above kind which represents an improvement on the prior art system with regard to modal noise and modal dispersion.

According to a first aspect of invention there is provided an optical communication system for the transmission of an optical signal/s, comprising at least one first optical transmitter coupled to at least one first optical receiver by a transmission link comprising a main optical waveguide in which only the fundamental mode can propagate above a cut-off wavelength, the operating wavelength being below the cut-off wavelength, said optical signal/s being transmitted in the fundamental mode wherein said transmission link contains sections of single mode optical waveguides to attenuate higher-order modes, respective sections being located at each end of said main optical waveguide and joined thereto at one end by a fusion splice, the other end being directly coupled to said optical transmitter/receiver.

According to a further aspect of the invention there is provided a transmitting device for an optical communication system wherein an optical signal is transmitted over a single-mode optical waveguide in the fundamental mode and at an operating wavelength lower than the cut-off wavelength of the optical waveguide, said transmitting device including an optical transmitter having a section of optical waveguide coupled thereto which is a single-mode optical waveguide at the operating wavelength, and wherein an optical connector is inserted in said section of optical waveguide, and that the free end of said section of optical waveguide is designed to be joined to the optical waveguide by a fusion splice.

According to a still further aspect of the invention there is provided a receiving device for an optical communication system wherein an optical signal is transmitted over a single-mode optical waveguide in the fundamental mode and at an operating wavelength lower than the cut-off wavelength of the optical waveguide, said receiving device including an optical receiver having a section of optical waveguide coupled thereto which is a single-mode optical waveguide at the operating wavelength, and wherein an optical connector is inserted in said section of optical waveguide, and that one end of said section of optical waveguide is coupled to the optical receiver, while the other, free end is designed to be joined to the optical waveguide by a fusion splice.

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

Fig. 1 illustrates the basic principle of the system according to the invention for unidirectional communication;

Fig. 2 shows a bidirectional system in which signals are transmitted at equal wavelengths using frequency-division multiplexing;

Fig. 3 shows a bidirectional system using wavelength-division multiplexing;

Fig. 4 shows a doubly bidirectional system using wavelength-division multiplexing, and

Fig. 5 shows a modification of the system of Fig. 4.

Referring to Fig. 1, the system comprises an optical transmitter S and an optical receiver E with an operating wavelength of about 790 nm, and the transmission medium is a 1300-nm single-mode optical waveguide 1 whose cut-off wavelength typically lies between 1100 nm and 1280 nm. Suitable steps are taken to ensure that transmission takes place only in the fundamental mode, although at the operating wavelength the higher-order mode group LP_{11} could also propagate in the optical waveguide 1.

According to the invention, at the transmitting end between the optical transmitter S and the optical waveguide 1 and at the receiving end between this optical waveguide 1 and the optical receiver E, there are single-mode optical-waveguide sections 2 and 3, respectively, which have a cut-off wavelength of, e.g., 640 nm and, thus, are single-mode optical waveguides at the operating wavelength. The cut-off wavelength could also be 790 nm, i.e., it only must be less than the operating wavelength. One end of each of the optical-waveguide sections 2 and 3 is spliced to the optical waveguide 1, and the other end is coupled directly to the optical transmitter S and the optical receiver E, respectively. The optical-waveguide sections 2 and 3 contain optical connectors 4 and 5, respectively.

The splices are fusion splices, which are designated throughout the figures by the reference numerals 20 and 21.

It is known that for practicability reasons, optical connectors must be present near the transmitter and near the receiver but in prior art systems, these connectors are located not within the optical-waveguide sections serving as mode filters, but at the junctions between these optical waveguide sections and the optical waveguide forming the transmission medium. Placing the optical connector within the single-mode optical-waveguide section 2 or 3 has the advantage that in the direction of transmission behind the connector, the higher-order mode LP_{11}, which, as is well known, may form in any optical connector as a result of mode conversion, cannot occur, because it cannot propagate in such an optical-waveguide section.

If the connector were located at the junction between the optical-waveguide section and the optical waveguide forming the transmission medium, LP_{01}/LP_{11} mode conversion would take place there, and because of the resulting modal noise in the optical waveguide 1, the signal-to-noise ratio would be reduced by 1.4 dB, as was determined in a laboratory experiment. Further, measurements have shown that at low-loss fusion spliced (<0.2 dB), each marked in Fig. 1 by a dot, LP_{01}/LP_{11} mode conversion occurs only to an insignificant extent.

In the system according to the invention, modal noise and modal dispersion due to LP_{01}/LP_{11} mode conversion are thus largely avoided.

The optical transmitter S, like the optical transmitter in the prior art system, is a 790-nm semiconductor laser of the kind commonly used for CD players, which is available at a low price.

The optical receiver E is a silicon photodiode, which is also available at low cost.

The optical transmitter is preferably a laser emitting several, e.g., 12 to 20, longitudinal modes. On the one hand, these 12 to 20 longitudinal, highly stable laser modes, whose energy propagates in the optical waveguide as an LP_{01} fundamental mode, cause mode partition noise due to the material dispersion of the optical waveguide, but on the other hand, such a multimode laser has the advantage that laser feedback noise and so-called laser-mode hopping are suppressed. This is due to the fact that the light of such a laser has a short coherence length, so that the light fed back to the laser cannot interfere with the laser light in the resonator. Multimode lasers with a coherence length of 1 mm or less are especially suitable. In a corresponding single-mode laser, such an undesirable effect would occur because of the greater coherence length. It has turned out that mode partition noise and material dispersion are more readily acceptable than laser feedback noise and laser-mode hopping, so that the multimode laser will be preferred to the single-mode laser.

If the communication system is to contain further optical connectors, e.g., within the optical waveguide 1, these connectors will be inserted not directly in this optical waveguide 1, but in optical-waveguide sections of the same kind as the optical-waveguide sections 2 and 3 which are then spliced into the optical waveguide 1.

The system according to the invention has the advantage of ensuring a high signal-to-noise ratio for short transmission links as are typical for the subscriber area (in an analog-signal-transmitting experimental system, the optical waveguide 1 had a length of 1.2 km, and the fibre pigtails were 2 m long.) This signal-to-noise ratio is so good that even the requirements placed on analog transmission, which are much more stringent than those placed on digital transmission, can be met.

For example, analog signals from several broadband or narrow-band channels can be transmitted in a frequency-division multiplex mode by modulating different RF carriers, suitable modulation methods being amplitude modulation, frequency modulation, or frequency-shift keying. For example, a (broadband) analog television signal (video signal and associated audio signal) is modulated onto an RF carrier with a frequency of 20.7 MHz or 38.9 MHz by amplitude or frequency modulation, and a (narrow-band) analog television signal is modulated onto an RF carrier with a frequency of 0.225 MHz by either of these modulation techniques, and the mixture of these two modulated RF carriers is used to drive the laser. At the receiving end, the two signals are separated from each other by electric filtering. An advantage of analog transmission over digital transmission is that the expensive analog-to-digital and digital-to-analog converters can be dispensed with, and that signal-processing devices available at low cost, such as filters, modulators, frequency converters, etc., can be employed.

In connexion with conventional analog transmission techniques, the optical communication system according to the invention permits extremely low-cost communication in the public subscriber area as well as in local networks ("LANs" - "subscriber premises networks").

As for the practical implementation of the system of Fig. 1, the following should be added. The optical transmitter S, together with the associated electric controller (not shown) and the mechanical holding devices (not shown), is housed in a case 6, in whose wall the part of the connector 4 associated with the transmitter (S) is mounted. One part of the optical-waveguide section 2 is thus located within the case, and the other outside the case. One end of the part located outside the case terminates in the part located within the case, and the other end is joined to the optical waveguide 1 by a fusion splice, indicated in the drawings by a dot. The same applies analogously to the receiver E, whose case is denoted by the reference numeral 7.

A bidirectional transmission system based on the above-explained principle of the invention will now be described with the aid of Fig. 2. In this example, a first optical transmitting and receiving device, housed in a case 10, is connected to one end of the optical waveguide 1 forming the transmission medium, and a second optical transmitting and receiving device, housed in a case 11, to the other. The first optical transmitting and receiving device, shown in the figure at the left, contains an optical transmitter S1 and an optical receiver E2 which operate at the same wavelength of 790 nm. Coupled to the transmitter S1 and the receiver E2 are optical-waveguide sections which are of the same kind as the optical-waveguide sections 2 of Fig. 1. The other ends of these optical-waveguide sections are connected to a fusion coupler 8 whose cut-off wavelength is chosen so that it is "single-mode" at the operating wavelength of 790 nm. The third end of the fusion coupler 8 is connected by a fusion splice to an optical-waveguide section of the same kind as the optical waveguide section 2 of Fig. 1, which contains a connector 4 and whose other end is spliced to the optical waveguide 1 by a fusion splice. In other words, Fig. 2 differs from Fig. 1 in that a fusion coupler 8 is spliced into the optical-waveguide section 2 between the optical transmitter and the optical connector 4 and has a receiver E2 spliced thereto.

Correspondingly, the transmitting and receiving device shown in the right-hand portion of Fig. 2, which is housed in a case 11, contains an optical transmitter S2, an optical receiver E1 having the same operating wavelength of 790 nm as the units S1 and E2 at the distant end, and a fusion coupler 9, which are connected together and to the optical waveguide

1 in a manner analogous to that explained above for the transmitting and receiving device 10.

This system can be used for bidirectional communication as follows, for example. In one direction, in Fig. 2 from the left to the right, a broadband analog signal modulated onto a 20.7-MHz carrier or a mixture of two or more modulated RF carriers is transmitted. This modulated carrier is applied to the input of the optical transmitter S1 of the transmitting and receiving device 10. In the distant transmitting and receiving device 11, this analog signal appears at the output of the optical receiver E1 and passes through a subsequent high-pass filter 12.

In the opposite direction, an analog or digital narrow-band signal modulated onto a 0.225-MHz carrier is transmitted, the modulated carrier being applied to the input of the optical transmitter S2 of the transmitting and receiving device 11. In the distant transmitting and receiving device 10, this signal appears at the output of the optical receiver E2 and passes through a subsequent low-pass filter 13. The low-pass filter 13 in the transmitting and receiving device 10 serves to attenuate the signal with the 20.7-MHz carrier frequency from the associated transmitter S1; similarly, the high--pass filter 12 in the transmitting and receiving device 11 serves to attenuate the signal with the 0.225-MHz carrier frequency from the associated transmitter S2.

This bidirectional communication system of Fig. 2 is suited, for example, for transmitting one or more broadband, and optionally, narrow-band signals in the higher frequency band from the exchange to the subscriber, and one or more digital or analog narrow-band signals in the lower frequency band in the opposite direction, i.e., from the subscriber to the exchange.

All properties and advantages mentioned and explained in connection with the unidirectional communication system of Fig. 1 also apply to the bidirectional system of Fig. 2, particularly the advantage that - here in both directions of transmission - the requirement for a high signal-to-noise ratio can be met, so that even analog transmission is made possible, i.e., that conventional low-cost transmission equipment can be employed.

In the embodiment of the invention described so far, the optical waveguide 1 is operated at only one wavelength, either for transmission in a single direction (Fig. 1) or for bidirectional transmission (Fig. 2). It is also possible, of course, to operate the optical waveguide 1 in a wavelength-division multiplex mode by connecting a second transmitting and receiving device to each end of the optical waveguide 1 via wavelength-division multiplexer/demultiplexers, these second transmitting and receiving devices having a second operating wavelength, receiving devices having a second operating wavelength, e.g., 840 nm. For this wavelength, too, low-cost lasers as are commonly used for laser printers are available. Aside from having a different operating wavelength, these second transmitting and receiving devices are identical in construction to the transmitting and receiving devices shown in Fig. 2, so they need not be explained again or shown in a drawing. Such a system with two transmitting and receiving devices at each end of the optical waveguide 1 can be used if two subscribers are to be supplied from an exchange over a single optical waveguide and also have to transmit signals to the exchange.

A further embodiment of the invention is shown in Fig. 2. Like in Fig. 2, an optical transmitting and receiving device 16, 17 is present at each end of the optical waveguide 1 and contains an optical transmitter and an optical receiver, so that bidirectional communication is possible. In each of the two transmitting and receiving devices 16 and 17, the operating wavelength of the optical transmitter is different from that of the optical receiver, and the fusion coupler 14, 15 is a wavelength-selective coupler which is "single-mode" at the two operating wavelengths and capable of separating optical signals with the different wavelengths, so that the receiver E2 in the transmitting and receiving device 16 can only be reached by light of one wavelength, e.g., 840 nm, and the receiver E1 in the transmitting and receiving device 17 by light of the other wavelength, e.g., 790 nm.

Instead of the fusion couplers 14 and 15, other wavelength-selective couplers can be used in conjunction with a single-mode fibre pigtail, e.g., sharp cut-off interference filters or grating couplers.

Because of the wavelength separation, the same frequencies can be used in both directions of transmission for modulating the optical transmitters, e.g., a 38.9-MHz carrier and, if necessary, further carriers, e.g., a 20.7-MHz carrier if analog signals are to be transmitted. It is also possible, of course, to transmit digital signals with this system, e.g., a 280-Mb/s signal from an exchange with the transmitting and receiving device 16 to a subscriber with the transmitting and receiving device 17, and a 140-Mb/s signal in the opposite direction. The system of Fig. 34 thus serves to transmit analog or digital signals using wavelength-division multiplexing and frequency-division multiplexing.

In the system of Fig. 3, like in the systems of Figs. 1 and 2, the transmission equipment required at the transmitters and receivers, such as modulators, converters, etc., is now shown. The other parts of the system of Fig. 3 are identical in construction to the correspondingly designated parts of Figs. 1 and 2, so they need not be explained again.

In a further embodiment of the invention, an additional transmitting and receiving device is coupled to each end of the optical waveguide 1. These additional transmitting and receiving devices operate in the same manner as the transmitting and receiving devices 16 and 17 of Fig. 3, but at a different pair of wavelengths, e.g., at the wavelength pair 1180 nm and 1220 nm. The two transmitting and receiving devices at each end of the optical waveguide 1 are then coupled to the latter by means of so-called bidirectional optical multiplexer/demultiplexers; in this case, too, the principle of the invention that the connectors necessary in the system are inserted in optical-waveguide sections which are "single-mode' at the operating wavelengths is applied.

In this embodiment, the fibre pigtail projecting from each of the two transmitting and receiving devices is spliced not directly to the optical waveguide 1 as in Figs. 1 to 3, but to two ends of a fusion coupler which has its third end spliced to the optical waveguide 1. This fusion coupler forms the bidirectional wavelength/division multiplexer/demultiplexer and, like the optical waveguide 1, is "single-mode" only clearly above the operating wavelengths. The same applied analogously to the connection of the two transmitting and receiving devices at the other end of the optical waveguide 1.

The advantages of the invention, which were explained above in connection with the embodiments described, also apply to communication in both directions with the aid of the second wavelength pair. As in the comparable example described above, such a system can be used if not only one, but two subscribers are to be connected to an exchange via a single optical waveguide to provide bidirectional communication for each subscriber.

Figs. 4 and 5 show further embodiments of the invention in which, like in the embodiment just described, not only one, but two bidirectional connections can be established over the optical waveguide 1. The system of Fig. 4 differs from the system of Fig. 3 as follows.

A bidirectional optical wavelength-division multiplexer/demultiplexer 22 is spliced between the fusion coupler 14 and the optical connector 4. Via this wavelength-division multiplexer/demultiplexer 22, a second optical transmitting and receiving device, consisting of a transmitter S3 and a receiver E4, is coupled to the optical-waveguide section 2. The pair of operating wavelengths of this second optical transmitting and receiving device differs from that of the first optical transmitting and receiving device, consisting of the transmitter S1 and the receiver E2. In the embodiment shown, the first transmitting and receiving device has the operating wavelengths 780 nm and 820 nm, and the second optical transmitting and receiving device has the operating wavelengths 1180 nm and 1220 nm. Aside from the fact that the two transmitting and receiving devices oprate at different wavelength pairs, there are no differences.

The bidirectional optical wavelength-division multiplexer/demultiplexer 22 ensures that the two wavelength pairs cannot reach the respective other transmitting and receiving device, but can reach the optical waveguide 1.

At the opposite end, the system of Fig. 4 differs from that of Fig. 3 in that a bidirectional optical wavelength-division multiplexer/demultiplexer 23 is spliced between the connector 5 and the fusion coupler 15. Via this bidirectional wavelength-division multiplexer/demultiplexer, a second optical transmitting and receiving device, consisting of an optical transmitter S4 and an optical receiver E3, which operate at the wavelength pair 1180 nm and 1220 nm, is connected to the optical waveguide 1. These two transmitting and receiving devices are connected to the device 23 via optical-waveguide sections 3 of the same kind as the optical-waveguide sections mentioned above.

Thus, not only one bidirectional connection is provided over the optical waveguide 1 (at a first pair of wavelengths), but a second, likewise bidirectional connection (at a second pair of wavelengths).

In this embodiment of the invention, too, the optical connectors and all wavelength-division-multiplexing/demultiplexing devices are contained in the optical-waveguide sections 2 and 3, so that the same advantages as those explained above are gained.

The system of Fig. 5 differs from that of Fig. 4 in that the connections between the bidirectional optical wavelength-division multiplexer/demultiplexer 23 and the two fusion couplers 15 are somewhat more complex than in Fig. 4. Seen from the coupler 15, each of these onnections consists of an optical-waveguide section 3 spliced to one end of the coupler 15, an optical waveguide 1 spliced to the optical-waveguide section 3, and an optical-waveguide section 3 spliced between this optical waveguide 1 and the bidirectional optical wavelength-division multiplexer/demultiplexer 23, with the optical-waveguide sections 3 containing optical connectors 24 and 25 which are mounted in case walls in a manner similar to that explained with reference to Fig. 1. As in all examples explained so far, the optical-waveguide sections 3 are single-mode optical waveguides at the operating wavelengths, whereas the optical waveguide 1 is the single-mode optical waveguide optimized for transmission in the 1300-nm range, which, however, is "single-mode" only clearly above the operating wavelength.

Both embodiments, Fig. 4 and Fig. 5, are suitable for connecting two or more subscribers to an exchange, shown in the figures at the left, with bidirectional communication being possible between the exchange and each of the subscribers. In Fig. 5, the device 23 associated with the subscribers is located further from the subscribers as in Fig. 4, so that more complex connections, containing not only optical-waveguide sections, must be provided between this device and the subscribers.

Unlike in the prior art system referred to at the beginning, the multiplexing/demultiplexing devices are contained not in the optical waveguide 1 operated below its cut-off wavelength, but in optical-waveguide sections operated above their cutoff wavelength.

The claims defining the invention are:

1. An optical communication system for the transmission of an optical signal/s, comprising at least one first optical transmitter coupled to at least one first optical receiver by a transmission link comprising a main optical waveguide in which only the fundamental mode can propagate above a cut-off wavelength, the operating wavelength of said optical transmitter and said first optical receiver being of a predetermined value and below the said cut-off wavelength, said optical signal/s being transmitted in the fundamental mode wherein said transmission link contains sections of single mode optical waveguides to attenuate higher-order modes, respective sections being located at each end of said main optical waveguide and joined thereto at one end by a fusion splice, the other end being coupled to said optical transmitter/receiver via optical connector means.

2. A system as claimed in claim 1, wherein the optical transmitter is a semiconductor laser emitting several longitudinal modes.

3. A transmitting device for an optical communication system wherein an optical signal is transmitted over a single-mode first optical waveguide in the fundamental mode and at an operating wavelength lower than the cut-off wavelength of the said optical waveguide, said transmitting device including an optical transmitter having a section of second optical waveguide coupled thereto which is a single-mode optical waveguide at the operating wavelength, and wherein an optical connector means is inserted in said section, and that the free end of said section is designed to be joined to the first optical waveguide by a fusion splice.

4. A transmitting device as claimed in claim 3, including means for modulating analog narrow-band and/or broadband electric signals onto RF carriers and applying the modulated RF carrier or a mixture of the modulated RF carriers as a control signal to the optical transmitter.

5. A receiving device for an optical communication system wherein an optical signal is transmitted over a single-mode first optical waveguide in the fundamental mode and at an operating wavelength lower than the cut-off wavelength of the optical waveguide, said receiving device including an optical receiver having a section of second optical waveguide coupled thereto which is a single-mode optical waveguide at the operating wavelength, and wherein an optical connector means is inserted in said section, and that one end of said section is coupled to the optical receiver, while the other free end is arranged to be joined to the first optical waveguide by a fusion splice.

6. A receiving device as claimed in claim 5, including means for separating a mixture of electric signals delivered by the optical receiver into individual modulated RF carriers and for demodulating the latter.

7. A system as claimed in claim 1 or 2, wherein fusion couplers are spliced into said sections of single mode optical waveguides, and wherein in addition to the said first optical transmitter a second optical receiver and, in addition to said first optical receiver, a second optical transmitter is coupled via the fusion couplers to the optical waveguide in such a manner that signals can be transmitted in both directions of transmission, all optical transmitters and receivers having the same operating wavelength, means being provided at the transmitters and receivers for transmitting signals in both directions using frequency-division multiplexing.

8. A transmitting device as claimed in claim 3 or 4, wherein it is expanded into a transmitting and receiving device by the addition of a fusion coupler spliced into the section of optical waveguide and a second optical receiver coupled via the fusion coupler to the section of optical waveguide for receiving signals from a distant transmitter, and wherein the second optical receiver has the same operating wavelength as the first optical transmitter of the transmitting and receiving device, the transmitting and receiving device including means for transmitting signals in both directions using frequency-division multiplexing.

9. A receiving device as claimed in claim 5 or 6, wherein it is expanded into a transmitting and receiving device by the additon of a fusion coupler spliced into the section of optical waveguide and a second optical transmitter coupled via the fusion coupler to the section of optical waveguide for transmitting signals to a distant second receiver, and wherein said second optical transmitter has the same operating wavelength as the first optical receiver of the transmitting and receiving device, the transmitting and receiving device including means for transmitting signals in both directions using frequency-division multiplexing.

10. A system as claimed in claim 1 or 2, wherein couplers are spliced into the sections of optical waveguide, and in addition to the first optical transmitter, a second optical receiver and, in addition to the first optical receiver, a second optical transmitter is coupled by means of the couplers to the optical waveguide in such a manner that signals can be transmitted in both directions, and wherein one transmitter-receiver pair has an operating wavelength different from that of the second transmitter-receiver pair, the couplers being wavelength-selective such that the signals

to be transmitted in both directions can be transmitted using wavelength-division multiplexing.

11. A transmitting device as claimed in claim 3 or 4, wherein it is expanded into a transmitting and receiving device by the addition of a coupler spliced into the section of the optical waveguide and a second optical receiver coupled through the coupler to the section of the optical waveguide for receiving signals from a distant second transmitter, and wherein the operating wavelength of the second optical receiver is different from that of the first optical transmitter of the transmitting and receiving device, the coupler being wavelength-selective such that the signals to be transmitted in the two directions of transmission can be transmitted using wavelength-division multiplexing.

12. A receiving device as claimed in claim 5 or 6, wherein it is expanded into a transmitting and receiving device by the addition of a fusion coupler spliced into the section of optical waveguide and a second optical transmitter coupled through the fusion coupler to the section of the optical waveguide for transmitting signals to a distant second receiver, and wherein the operating wavelength of the second optical transmitter is different from that of the first optical receiver of the transmitting and receiving device, the fusion coupler being wavelength selective such that the signals to be transmitted in the two directions of transmission can be transmitted using wavelength-division multiplexing.

13. A system as claimed in claim 10, wherein bidirectional optical wavelength-division multiplexer/demultiplexers are inserted in the optical-waveguide sections, and wherein a third optical transmitter and a third optical receiver are connected via said bidirectional optical wavelength-division multiplexer/demultiplexers in such a way that two or more bidirectional connections exist simultaneously over the optical waveguide by wavelength-division multiplex operation.

DATED THIS TWENTY-SIXTH DAY OF JULY 1991

ALCATEL N.V.

AUSTRALIAN PATENT OFFICE

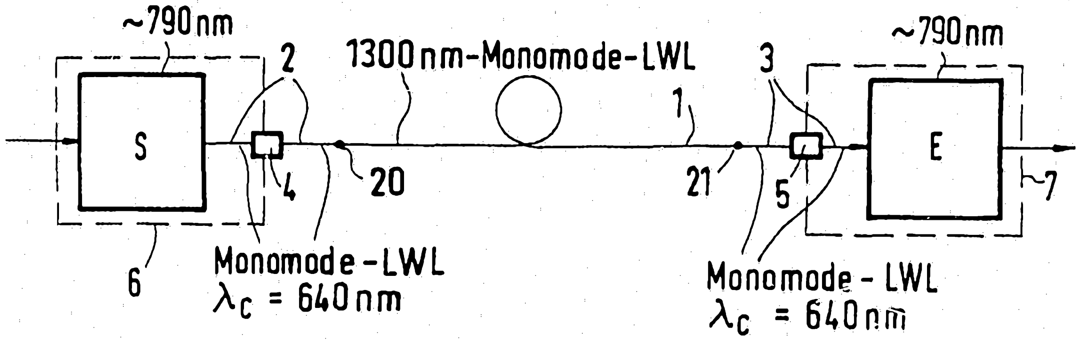

FIG.1

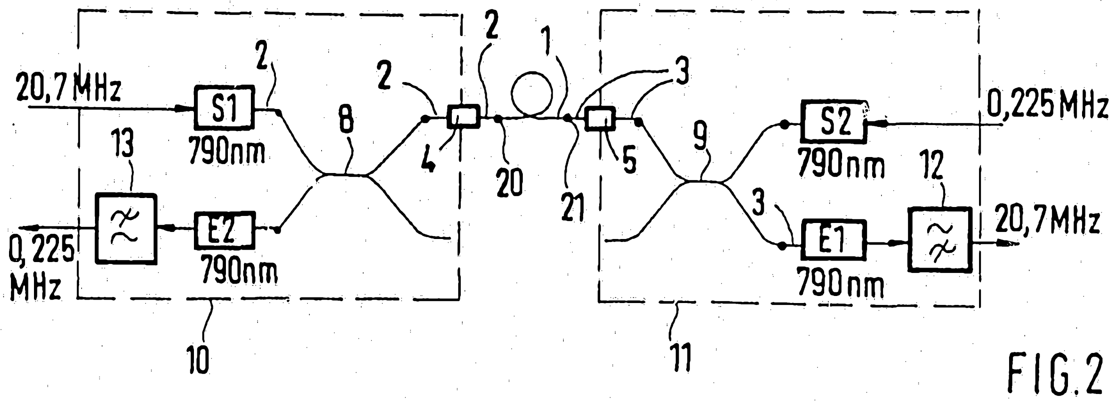

FIG.2

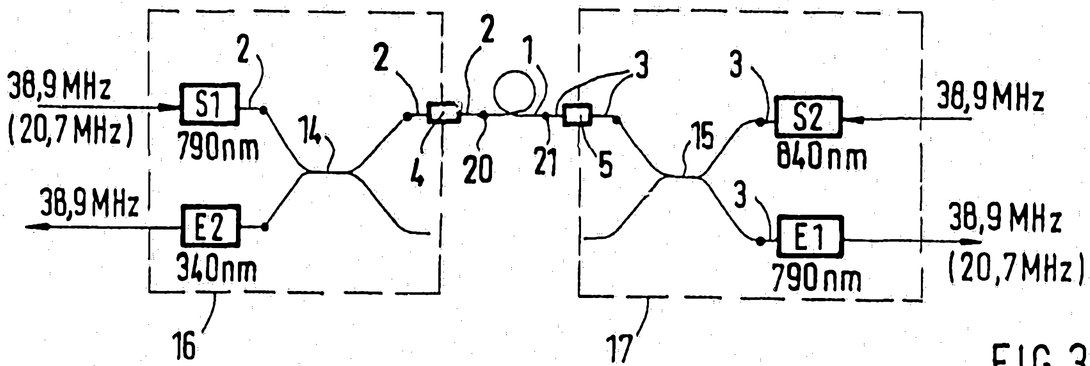

FIG.3

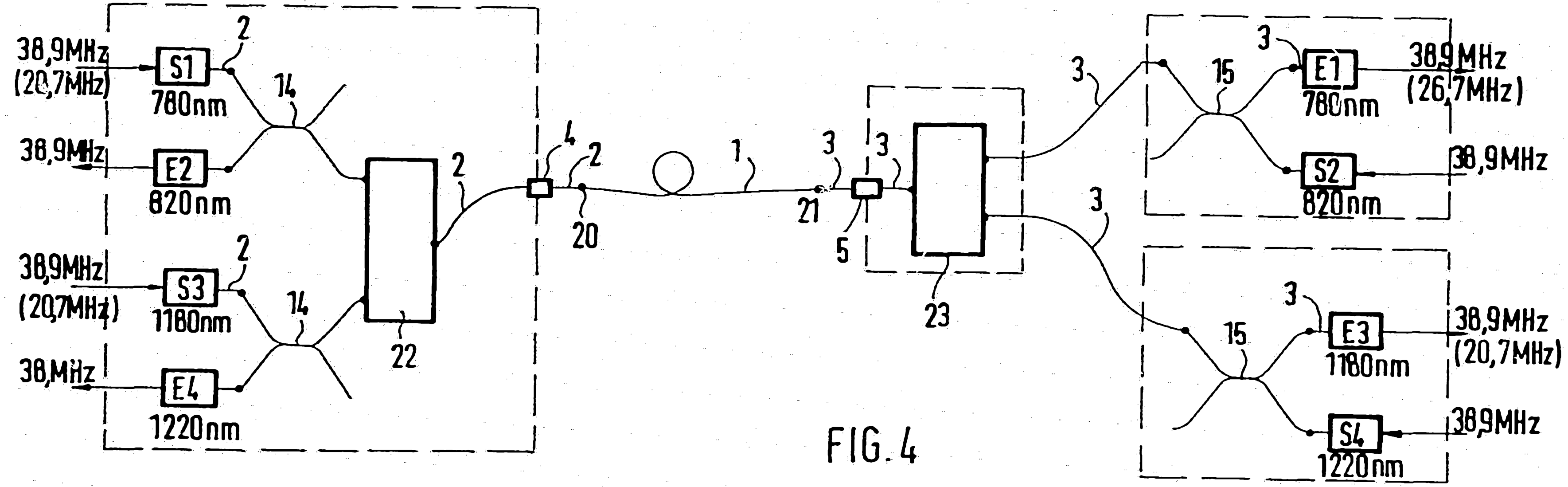
38,9MHz
(20,7MHz)
S1
780nm
38,9MHz
E2
820nm
38,9MHz
(20,7MHz)
S3
1180nm
38,MHz
E4
1220nm
2
14
22
4
20
1
3
21
5
23
15
E1
780nm
38,9MHz
(26,7MHz)
S2
820nm
38,9MHz
E3
1180nm
38,9MHz
(20,7MHz)
S4
1220nm
38,9MHz

FIG. 4

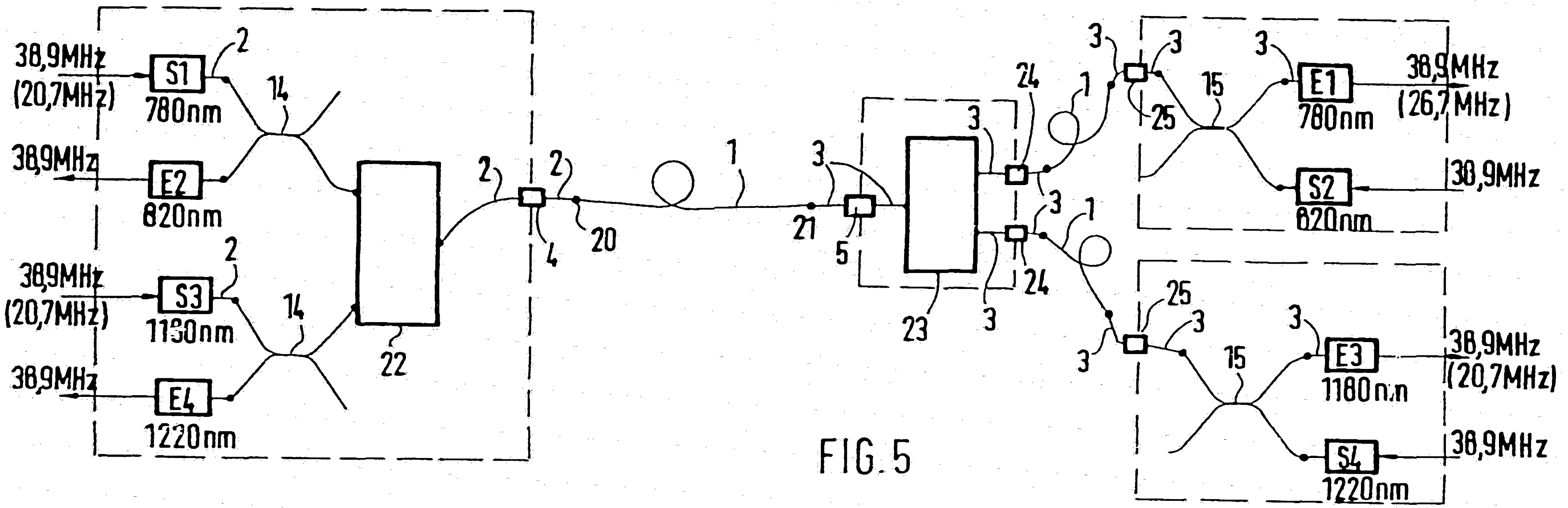
38,9MHz
(20,7MHz)
S1
780nm
38,9MHz
E2
820nm
38,9MHz
(20,7MHz)
S3
1180nm
38,9MHz
E4
1220nm
2
14
22
4
20
1
3
21
5
23
24
25
15
E1
780nm
38,9MHz
(26,7 MHz)
S2
820nm
38,9MHz
E3
1180nm
38,9MHz
(20,7MHz)
S4
1220nm
38,9MHz

FIG. 5