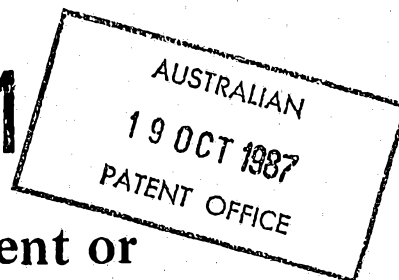


FORM 1

COMMONWEALTH OF AUSTRALIA
PATENTS ACT 1952

596451



Application for a Standard Patent or
A Standard Patent of Addition

APPLICATION ACCEPTED AND AMENDMENTS

ALLOWED 21-2-90

We, ALCATEL N.V. of De Lairesestraat 153,
1075 HK 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 3637097.5 & P 3709678.8

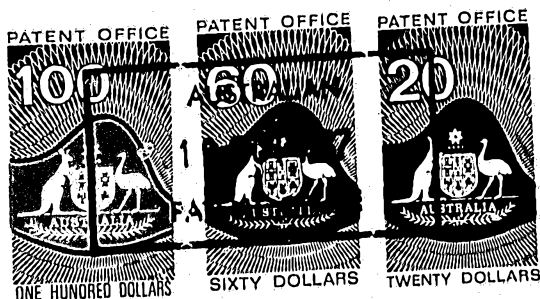
Name of Convention country in which basic application was
filed Germany

Date of basic application 31 October 1986 & 24 March 1987

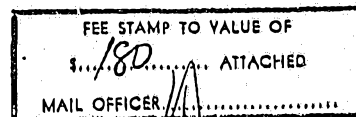
Our address for service is:

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

Dated this Sixteenth day of October 19 87



ALCATEL N.V.



BY: M. Conist
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, PATRICK MICHAEL CONRICK,
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.

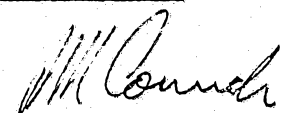
2. The basic application as defined by Section 141
of the Act ~~was~~ were made in Germany
on 31 October 1986 & 24 March 1987
by STANDARD ELEKTRIK LORENZ AG

3. DIETER KUPPERS, of Greutherstr. 23, 7000 Stuttgart 31, Germany;
KLAUS HERSE, of Blammerbergstr. 81, 7252 Weil der Stadt, Germany;
KATE HIEPE-WOHLLEBEN, of Neukollner Str. 7, 7250 Leonberg, Germany;
MANFRED KAISER, of Zeppelinstr. 2, 7254, Hemmingen, Germany;
FRIEDEMANN MOHR, of Staufenstr. 6, 7253 Renningen, Germany and
HORST OHNSORGE, of Zellerstr. 4, 7149 Freiberg/N, Germany
~~xxx~~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 applications 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 16th day of October 19~~8~~ 87
ALCATEL N.V.


.....
Signature of Declarant

To: The Commissioner of Patents.

(12) PATENT ABRIDGMENT (11) Document No. AU-B-79916/87
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 596451

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OPTICAL COMMUNICATION SYSTEM

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FRIEDEMANN MOHR; HORST OHNSORGE

(74) Attorney or Agent
STANDARD TELEPHONES & CABLES

(56) Prior Art Documents
AU 68608/87 H04B 9/00
AU 573684 38056/85 H04B 9/00
AU 494042 75802/74 H04B 9/00

(57) Claim

1. A broadband optical communication system, particularly for a subscriber area, comprising at least one optical transmitter, at least one optical receiver, and an optical waveguide in which only the fundamental mode can propagate above a cut-off wavelength, wherein the optical transmitter and the optical receiver are a semiconductor laser and a semiconductor photodiode, respectively, whose operating wavelengths are below the cutoff wavelength of the optical waveguide, and that the laser is coupled to and precisely fixed in relation to the optical waveguide in such a way that only a single mode can be excited in the wavelength, and wherein the coupling of the laser to the optical waveguide is accomplished by joining that

(11) AU-B-79916/87
(10) 596451

-2-

end of the optical waveguide into which the laser light is to be coupled to the light emitting surface of the laser by means of an optical adhesive having a refractive index greater than the refractive index of the environment surrounding the coupling of the laser and the waveguide.

596451

ORIGINAL

This document contains the
amendment made under
Section 49 and is correct for
printing.

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 a broadband optical communication system, particularly for a subscriber area, comprising at least one optical transmitter, at least one optical receiver, and an optical waveguide in which only the fundamental mode can propagate above a cut-off wavelength, e.g., 1,280nm. A system of this kind is described in "ntz", Vol. 39 (1986), No. 7, pp. 484-489. In that printed publication, it is held that a single-mode optical waveguide, which has the smallest loss and the largest bandwidth in the optical long-wave range from 1300 nm to 1600 nm, is the transmission medium suitable for all broadband optical communication systems, including
10 the subscriber area, where the subscribers are connected to the local exchange in a star network.

As is well known, such single-mode optical wavelengths are "single-mode" only for wavelengths above a cutoff wavelength (which depends on the core diameter and the refractive indices of the core and cladding), i.e., above this cutoff wavelength, only the fundamental mode can propagate. At wavelengths below this cutoff wavelength, two or more modes can propagate ("ntz", Vol. 39 [1986], pp. 454 to 459).

In the first-mentioned publication it is stated that the optical transmitters and receivers must be tuned to the optical long-wave range (1300 nm to 1600 nm), and that great efforts must be made to achieve low-cost manufacture, which is not yet possible at this time. A low-cost solution to the problem of transmitting optical signals over optical
20 wavelengths in the subscriber area is not given in the printed publication.

In "ntz", Vol. 39 (1986), No. 7, pp. 502 to 508, it is also held that the single-mode optical wavelength is the optical-wavelength type best suited for the optical subscriber line, but that the high costs of the necessary optical-to-electric transducers prevent an early introduction of broadband optical subscriber lines.

It is, therefore, an object of the present invention to remedy this drawback and provide a system which represents a low-cost solution particularly for applications in the subscriber area.

According to the invention there is provided a broadband optical communication system, particularly for a subscriber area, comprising at least one optical transmitter, at least one optical receiver, and an optical waveguide in which only the fundamental mode can propagate above a cut-off wavelength, e.g., 1,280nm wherein the optical transmitter and the optical receiver are a semiconductor laser and a semiconductor photodiode, respectively, whose operating wavelengths are below the cutoff wavelength of the optical waveguide, and that the laser is coupled to the optical waveguide in such a way that only a single mode can be excited in the wavelength.

The invention has the following advantages:

For the optical transmitters and optical receivers, semiconductor components are used which are already now available at low cost. Thus, the biggest obstacle to the introduction of a low-cost optical subscriber line is removed.

The transmission medium used is the optical-waveguide type which has gained acceptance for long-distance applications and which has the lowest loss and the lowest dispersion in the waveguide range from 1300 to 1600 nm, i.e., which is currently the optimum optical-waveguide type for long-distance applications and for such wavelengths. The use of this type saves the cost of developing an optical waveguide specifically designed for the subscriber area. Since, because of the large number of subscriber lines in the subscriber area, considerably greater quantities have to be produced than if the waveguide were used exclusively for long-distance applications, economic production of this type of optical waveguide is made possible at all.

The laser-waveguide coupling in accordance with the invention is a very simple solution to the coupling problem described in the literature, "ntz", Vol. 39 (1986), No. 7, pp. 502 to 508, which is less severe for applications in the subscriber area than for long-distance applications but still is described as a hitherto unsolved problem.

10 The advantage of the laser-waveguide coupling by means of an adhesive over a lens coupling, with which the laser light would exit into the air, is that the angle of emergence of the laser light from the laser is decreased, because the adhesive has a higher refractive index than air. Thus, the adhesive, too, provides a certain focusing action. In addition, the coupling by means of an adhesive has the advantage that light transmitted in the cladding either due to back-scattering or to reflections within the optical transmission path cannot reach the laser and deteriorate the properties of the latter, as would be the case if a lens were used to couple the laser light into the optical waveguide.

20 The invention is also applicable to a bidirectional communication system since it turned out that the fused-fibre couplers commonly used there to separate the two directions of transmission and the wavelengths do not impair the stability of the transmitted fundamental mode; on the contrary, these couplers even suppress any higher-order modes that may arise anywhere on the transmission path.

According to the invention, it is also possible to transmit two optical signals of the same wavelength but with different modes over the optical waveguide. This saves the considerable costs that would result from the use of different wavelengths.

Embodiments of the invention will now be described with reference to the accompanying drawing, in which:

Fig. 1 shows the basic principle of the combination of an electric-to-optical transducer, an optical-to-electric transducer, and a single-mode optical waveguide in accordance with the invention;

Fig. 2 shows an embodiment of the laser-waveguide coupling;

Fig. 3 shows an application of the invention to a bidirectional optical communication system;

Fig. 4 shows a bidirectional communication system in accordance with the invention;

Fig. 5 shows a unidirectional communication system in accordance with the invention; and

Fig. 6 shows an embodiment of a modal filter.

In the optical communication system of Fig. 1, like in all optical communication systems, an optical transmitter S, also called "electric-to-optical transducer", is connected via an optical waveguide 1, used as the transmission medium, to an optical receiver E, also called "optical-to-electric transducer". A feature of this system is that a 1300-nm single-mode optical waveguide is combined with an optical transmitter and an optical receiver whose operating wavelengths lie in the range of 800 nm and, thus, clearly below the cutoff wavelength of the single-mode optical wavelength, which is suitable for transmission in the range of 1300 nm to 1600 nm. Single-mode operation is necessary in order to be able to transmit digital signals at high bit rates, e.g., 140 Mb/s, error-free. If the light propagated in the optical waveguide in two or more modes, this would be impossible because of the known effect of modal dispersion.

According to the invention, the necessary single mode operation is achieved by coupling the light to the optical waveguide in such a way that only a single mode will be excited, while higher-order modes, which, since the laser's operating wavelength lies below the cutoff wavelength of the optical waveguide, could propagate in the waveguide too, will not form at all. The optical transmitter S is a GaAlAs laser operating at 800 nm, and

the receivers are silicon photodiodes, whose properties are precisely known and which are currently the least expensive transmitting and receiving devices obtainable GaAlAs lasers with a wavelength of 780 nm, for example, are produced in millions for use in CD players.

Since the single-mode waveguide 1 has an attenuation of about 2.5 dB/dm at an operating wavelength of 780 nm, while the attenuations at 1300 nm and 1550 nm are 0.4 dB/km and 0.2 dB/km, respectively, the attenuation of the novel system is higher than that of the system proposed in the literature, which operates at 1300 or 1500 nm, but this attenuation increase can be readily tolerated for applications at the subscriber level, where the length of the transmission path from the local exchange to the subscriber does not exceed 12 km, in 95% of all cases even 6 km, since a sufficient reserve is available in view of the transmitter power and the receiver sensitivity. For all applications in which such an attenuation can be tolerated, i.e., not only for applications in the subscriber area, the invention is the appropriate solution.

If single-mode operation is to be achieved at a wavelength at which multimode operation would also be possible, the coupling of the laser to the optical waveguide is of primary importance, because, firstly, only one mode, preferably the fundamental mode LP₀₁, is to be excited as far as possible, and secondly, the coupling must be stable in time and insensitive to temperature variations. If the coupling shifts, the next-higher-order mode LP₁₁ will be excited, so that the necessary single-mode operation will be adversely affected.

The coupling of a laser to a single-mode optical waveguide in accordance with the invention will now be explained with the aid of Fig. 2. A laser 2 with an active layer 3 is fastened to a substrate 4. The single-mode optical waveguide 1, whose core is designated 5, is positioned relative to the laser 2 in such a way that its end face into which the laser light is to be coupled is as close as possible to the light-emitting sur-

face of the laser 2. The optical waveguide is a so-called fibre pigtail and has a length of about 1 m. The waveguide end facing the laser 2 is adjusted so that the near field observable at the end of its length of 1 m shows an intensity distribution which is exactly equal to that of the fundamental mode LP₀₁. For the adjustment, a positioning table can be used with which the optical waveguide is shiftable in all three co-ordinate directions with high accuracy.

Prior to the adjustment, an adhesive 6 is applied to that surface of the laser 2 to which the optical waveguide is to be coupled, and after the adjustment, this adhesive is cured by irradiation with ultraviolet light. It must be ensured that the end face of the optical waveguide joined to the laser is separated from the laser by a distance of about 20 μm . A shorter distance may result in the optical waveguide coming into contact with the light-emitting surface of the laser and damaging this surface, and a greater distance would degrade coupling efficiency. To stabilize the adhesive joint between the end face of the optical waveguide and the laser surface, the optical waveguide is cemented onto a support 7 at a short distance from the laser. The stability of the coupling is of fundamental importance to reliable single-mode operation. A slight change in the coupling in the form of a longitudinal displacement of the fibre by as little as 0.1 μm would immediately result in the excitation of the unwanted next higher-order mode LP₁₁.

In tests, the coupling obtained by using an adhesive as described proved to be extremely rugged. It was stable to vibration and exhibited no variation with time. In view of the properties of the adhesive, no change in the coupling is to be expected even over periods of years. The adhesive used is a commercially available optical cement which, because of its good permanent properties, is recommended by the manufacturer for splicing optical waveguides. Favourable properties of this cement are, for example,

its refractive index of 1.56 and its long-term temperature stability from -80°C to +90°C.

After this description of the laser-waveguide coupling, the characteristics of the system of Fig. 1, which uses this coupling, will be dealt with. The CD laser HL 7801 of Hitachi, which has an operating wavelength of 780 nm, has the property of becoming multimode when driven with high-frequency signals. The modes formed are longitudinal modes which do not appreciably influence the form of the emergent light cone in which the fundamental mode is emitted. Thus, the excitation of the fundamental mode as the single mode remains independent of whether the laser is unmodulated or is modulated with a high-frequency signal. In any case, single-mode light propagation was observed in the optical waveguide. The higher-order modes which are present in the emitted laser light when the laser is modulated with a high-frequency signal result in an increase of the linewidth of the emitted light. Because of the material dispersion of the optical waveguide, the light pulses of the transmitted optical signal are thus subjected to increased delay distortion. This delay distortion, however, can be tolerated without a substantial deterioration of transmission quality if the length of the optical-waveguide link is only a few kilometers, as is the case with subscriber lines.

An experiment has shown that digital signals can be transmitted at a bit rate of 34 Mbs and with sufficient quality over a 12-kilometer link of the kind described. Even after 12 km, no components of the higher-order mode LP₁₁ could be observed.

It is quite surprising that the excited fundamental mode remains stable over the fibre length and does not transform into higher-order modes. This was not necessarily to be expected, for there is no equation in the literature with the aid of which it would have been possible to predict the coupling length, i.e., the length after which the light energy coupled into the fibre in a single mode divides evenly between the modes which are pos-

sible in the optical waveguide, i.e., the modes LP01 and LP11. The stability of the fundamental mode in the single-mode optical waveguide is presumably connected with the fact that the fundamental mode LP01 is greatly different from the next higher-order mode LP11 in the spatial energy distribution.

10 In optical communication systems, connectors and splices are commonly used. For example, the fibre pigtail joined to the laser with an adhesive is connected with the waveguide by means of a connector, and a corresponding connection is made at the receiving end in the optical receiver E. To demonstrate the realizability of the system in accordance with the invention, it was important to show that neither at connectors nor at splices, the excited fundamental mode changes into one or more higher-order modes. Surprisingly, the fundamental mode turned out to be extremely stable in this respect, too, and no degradation of transmission performance due to the insertion of connectors or splices into the link was determined if connectors with losses lower than 1 dB were used and if the splices were made expertly.

20 In connection with the above-mentioned adhesive 6 for obtaining a stable laser-waveguide coupling, two advantageous properties should be mentioned:

For matching the refractive index of the active layer 3 of the laser 2, which lies in the range from 3 to 5, to the refractive index of the core 5 of the optical waveguide 1, which is 1.45, the adhesive refractive index of 1.56 is better suited than the refractive index of air, which is 1. The refractive index of the adhesive, which is higher than that of air, ensures that the laser light emerges from the laser, and is launched into the core of the optical waveguide, at a smaller angle than would be the case if the space between the laser and the optical waveguide were an air gap. The adhesive thus provides focusing action and, consequently, increases the coupling efficiency.

30

The second advantageous property is as follows. The laser-waveguide coupling of Fig. 2 has a coupling loss of 6 dB, whereas a lens coupling would have a loss of only 3 dB, but it is this increased loss of the coupling in accordance with the invention which has the advantage that light transmitted in the cladding back to the laser due to reflections at connectors or due to Rayleigh scattering does not adversely affect the laser. At a wavelength of 800 nm, light scattering is much more intensive than at 1300 nm and 1500 nm. If a lens were used to accomplish the laser-waveguide coupling, the cladding light scattered from the optical waveguide back to the laser would be focused on the laser, too, and would degrade the laser performance by causing line narrowing as well as abrupt changes in frequency and intensity. By contrast, the adhesive joint of Fig. 2 has the advantageous effect that much less light is reflected into the laser than if a lens were present.

If the system according to the invention is used in the subscriber area, it is desirable for the transmission to take place in both directions over a single optical waveguide. It turned out that even bidirectional operation over a fibre-optic link containing conventional fused-fibre directional couplers for wavelength-selective direction separation is possible on the principle of the invention.

Fig. 3 shows such a system for bidirectional optical transmission using different wavelengths. A wavelength of 780 nm is used for one direction of transmission from a transmitter S1 to an optical receiver E1, and a wavelength of 830 nm for the opposite direction from a transmitter S2 to a receiver E2.

To separate the two directions of transmission, wavelength-selective directional couplers 8 and 9 in the form of conventional fused-fibre couplers are present at both ends of the transmission path. Like in Fig. 1, the transmission medium is a single-mode optical wavelength 1 whose cutoff

wavelength is just under 1300 nm and which, like the optical waveguide in the system of Fig. 1, is operated clearly below this cutoff wavelength.

The reference numerals 10 denote fibre-optic connectors which connect the ends of the fused-fibre directional couplers to laser pigtails or to the optical waveguide 1.

10 Surprisingly it turned out that light with a wavelength of 780 nm which is coupled into the port 11 of the coupler 8 in the fundamental mode emerges from the port 13 of the coupler in pure form in the same mode, and that light with a wavelength of 830 nm coupled into the port 13 of the coupler 8 in the fundamental mode appears at the port 12 in pure form in the same mode; the same applies analogously to the coupler 9. In other words, single-mode operation in the multimode region of a single-mode optical waveguide is possible with conventional couplers even in bidirectional wavelength-division multiplex. It was even found that the fused-fibre directional couplers suppress higher-order modes if such modes should form anywhere on the transmission path or be excited by imperfect coupling.

20 In a system as shown in Fig. 3, a low-cost bidirectional broadband optical subscriber line can thus be implemented with a single optical waveguide. A link as shown in Fig. 3 with a length of 5.5 km was tested at a bit rate of 140 Mbs in the bidirectional mode using the two wavelengths specified above, and a stable bit-error rate of 10 to the power -9 was achieved.

Also within the scope of the invention are systems in which, in addition to the fundamental mode, higher-order modes are excited and transmitted in a greatly reduced but still observable measure, and in which these higher-order modes are suppressed by suitable mode filters, such as the above-mentioned fused-fibre directional couplers, at the end of the transmission path before the light enters the optical-to-electric transducer, because such systems, too, make use of the principle of the invention to

use a single-mode optical waveguide not in its single-mode wavelength range as in its typical application, but in its multimode operation.

A coupling corresponding to Fig. 2 is also possible between the optical waveguide and the photodiode at the receiving end, both in systems according to the present invention and in any other system.

In the following, an advantageous aspect of the invention will be described with the aid of Figs. 4 and 5, which permits each of two optical signals to be transmitted over the optical waveguide in a single mode using only a single wavelength which, in accordance with the principle of the invention explained above, lies below the cutoff wavelength of the optical waveguide.

Fig. 4 shows a bidirectional optical communication system with a single optical waveguide 1 as the transmission medium. Unlike in the system of Fig. 3, the optical signals to be transmitted in the two directions have the same wavelength. Coupled to each end of the optical waveguide 1 is a semiconductor laser S1, S2. These two optical transmitters operate at the same wavelength, which is so chosen with regard to the optical waveguide 1 that only the fundamental mode LP01 and the next higher-order mode LP11 can propagate in the optical waveguide 1. With respect to the coupling of the two optical transmitters to the optical waveguide 1, the statements made above in connection with Fig. 1 apply, namely that the coupling is so constituted that the output of the optical transmitter is coupled into the optical waveguide 1 only in the fundamental mode LP01.

At the two terminals, modal filters MF1 and MF2 are inserted in the optical waveguide 1 near the transmitters. These modal filters do not influence an optical signal which is guided in the fundamental mode. Anywhere on the transmission path between the two modal filters, preferably in the area of a terminal, in the embodiment of Fig. 4 near the transmitter S1, the optical waveguide contains a modal coupler MK which has

erty of converting an optical signal arriving in the fundamental

to the next higher-order mode LP11, and this in each of the two directions of transmission. A modal coupler suitable for this purpose is described in "Optics Letters", March 1986, Vol. 11, No. 3, pp. 177 to 179.

The optical signal coupled into the optical waveguide by the transmitter S1 is thus transmitted to the modal coupler MK in the fundamental mode LP01, and from there to the distant terminal in the next higher-order mode LP11. In the opposite direction, the optical signal coupled into the optical waveguide by the transmitter S2 is transmitted to the modal coupler MK in the fundamental mode LP01, and from there to the modal filter MF2 in the next higher-order mode LP11. Each of the two modal filters MF1 and MF2 couples the optical signal transmitted in the higher-order mode LP11 out of the optical waveguide and passes it to the associated optical receiver E1, E2. The receiver E1 thus receives the optical signal from the transmitter S1, and at any point of the transmission path it is ensured that the two existing optical signals have different modes.

There is no coupling of components of one signal to the other signal since, as mentioned above, the two modes LP01 and LP11 are greatly different with respect to their spatial energy distribution over the cross section of the optical waveguide 1. Each of the two modes thus has a high stability.

If a small portion of a transmitted signal converted to the other mode, this would only result in a corresponding loss of power. The converted portion would not strike a receiver anywhere, and would thus in no way interfere with a signal transmission.

The system of Fig. 4 may be called a "bidirectional modal multiplex system", which, because of the uniform transmitters and the uniform receivers, is superior to a bidirectional wavelength-division-multiplex system in terms of cost and offers all advantages mentioned in connection with the system of Fig. 1.

In the simplest case, the modal filters MF1 and MF2 for coupling out the optical signal transmitted in the higher-order mode LP11 and passing it to the receiver will be an optical-waveguide section as shown in Fig. 6, which is reduced in diameter and from which the plastic coating was removed ("taper"). In the region of the reduced cross section, only the fundamental mode LP01 can propagate,, so that the other optical signal, which is present in the higher-order mode LP11, is radiated from this section into the environment and reaches an optical receiver E located in the environment. The region of the optical-waveguide section of reduced cross section is preferably embedded in a medium which protects the surface of the optical-waveguide section and focuses the radiation emerging from that region on the optical receiver E.

Another type of modal filter which contains a coupler is described in "Optics Letters", Vol. 11, No. 9, September 1986, pp. 581 to 583.

Fig. 5 shows an optical communication system for transmitting two optical signals at a single operating wavelength in a unidirectional mode.

In this case, the two semiconductor lasers used as the optical transmitters S1 and S2 are coupled to one end of the optical waveguide 1, and the associated optical receivers E1 and E2 to the other end. For the operating wavelengths of the transmitters and receivers in relation to the transmission characteristics of the optical waveguide 1, the same assumptions are made as in the bidirectional system of Fig. 4.

The optical transmitter S1 couples its output through a fused-fibre coupler 21 into the optical waveguide 1 in the fundamental mode LP01. In this fundamental mode, the signal passes through the optical waveguide, including a modal filter MS inserted therein, and reaches an optical receiver E1. The second optical transmitter S1 couples its output in the fundamental mode LP01 into a fibre pigtail 20 coupled to the optical waveguide 1 via the coupler 21. This fibre pigtail 20 contains a modal coupler MK which converts the fundamental mode LP01 to the next higher-order mode

LP11, so that this optical signal propagates down the optical waveguide 1 in the higher-order mode until it is coupled out of the optical waveguide 1 in the modal filter MF and reaches the optical receiver E2. The reference numerals 22 denote fibre-optic connectors which connect the ends of the fused-fibre coupler 21 to fibre pigtails or to the optical waveguide 1. In Figs. 4 and 5, the modal coupler can be inserted into the optical waveguide by using connectors or splices.

In this system, care must be taken to ensure that no unwanted mode conversion takes place, because otherwise one of the receivers might receive an optical signal not destined for it.

Both the system of Fig. 4 and that of Fig. 5 work on the fundamental principle of the invention that for each of the optical signals to be transmitted, transmission takes place in a single mode although at the operating wavelength chosen, a second mode could propagate as well.

The claims defining the invention are as follows:

1. A broadband optical communication system, particularly for a subscriber area, comprising at least one optical transmitter, at least one optical receiver, and an optical waveguide in which only the fundamental mode can propagate above a cut-off wavelength, wherein the optical transmitter and the optical receiver are a semiconductor laser and a semiconductor photodiode, respectively, whose operating wavelengths are below the cutoff wavelength of the optical waveguide, and that the laser is coupled to and precisely fixed in relation to the optical waveguide in such a way that only a single mode can be excited in the wavelength, and wherein the coupling of the laser to the optical waveguide is accomplished by joining that end of the optical waveguide into which the laser light is to be coupled to the light emitting surface of the laser by means of an optical adhesive having a refractive index greater than the refractive index of the environment surrounding the coupling of the laser and the waveguide.

2. A system as claimed in claim 1, wherein the optical waveguide is operated bi-directionally using wavelength-division multiplexing, and that as direction-separating/direction-combining devices, wavelength-division-multiplexer/demultiplexers in the form of fused-fibre directional couplers are used.

3. A system as claimed in claim 2, wherein the cut-off wavelength of the waveguide is 1,280nm and wherein the two wavelengths for the two directions of transmission are 780 nm and 830 nm.

4. A system as claimed in any one of claims 1 to 3, wherein a second optical transmitter and a second optical receiver are provided whose operating wavelengths are equal to those of the first optical transmitter and the first optical receiver respectively, and are so chosen that only the fundamental mode LP01 and the next higher-order mode LP11 can propagate in the optical waveguide, and in that the optical transmitters and the optical receivers are coupled to the optical waveguide in such a way that two op-



tical signals are transmitted unidirectionally or bidirectionally in different modes.

5. A system as claimed in claim 4, wherein the optical waveguide is operated bidirectionally, at one end of the optical waveguide, the first optical transmitter couples its optical output signal into the optical waveguide in the fundamental mode LP01, that at the other end, the second optical transmitter couples its optical output signal into the optical waveguide with the same wavelength and also in the fundamental mode LP01, that the optical waveguide contains a modal coupler which converts the transmitted optical signal from the fundamental mode LP01 to the next higher-order mode LP11 in each of the two directions of transmission, and between each of the first and second transmitters and the modal coupler, the optical waveguide contains respective first and second modal filters which couple the optical signal transmitted to the respective end of the waveguide, which is present in the higher-order mode LP11, from the optical waveguide to the associated optical receiver.

6. A system as claimed in claim 4, wherein the optical waveguide is operated unidirectionally, and wherein the first optical transmitter and the second optical transmitter are coupled to one end of the optical waveguide in such a manner that the optical output signal of the first optical transmitter is coupled into the optical waveguide in the fundamental mode LP01, while the optical output signal of the second optical transmitter is coupled in the fundamental mode LP01 into an optical-waveguide pigtail containing a modal coupler which converts it to the next higher-order mode LP11 and couples it into the optical waveguide in this mode, and wherein at the other end of the optical waveguide, the optical waveguide contains a modal filter which allows the optical signal transmitted in the fundamental mode LP01 to propagate along the optical waveguide up to the first optical receiver and couples the optical signal transmitted in the



higher-order mode LP11 from the optical waveguide to the second optical receiver.

7. A system as claimed in claim 5 or claim 6, wherein the modal filter is a section of optical waveguide whose diameter is such that the optical signal transmitted in the higher-order mode LP11 cannot propagate any further and is radiated into the environment of the optical waveguide section for reception by the receiver intended therefor, whereas the optical signal transmitted in the fundamental mode LP01 is transmitted by the optical waveguide section.

8. A broadband optical communication system, substantially as herein described with reference to Figs. 1 to 6 of the accompanying drawings.

DATED THIS FIRST DAY OF FEBRAURY, 1990

ALCATEL N.V.



FIG. 1

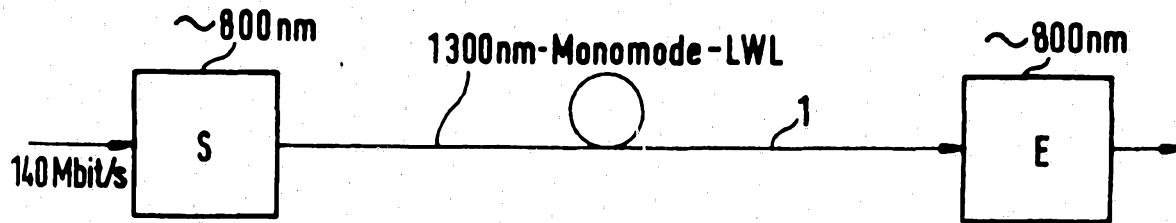


FIG. 2

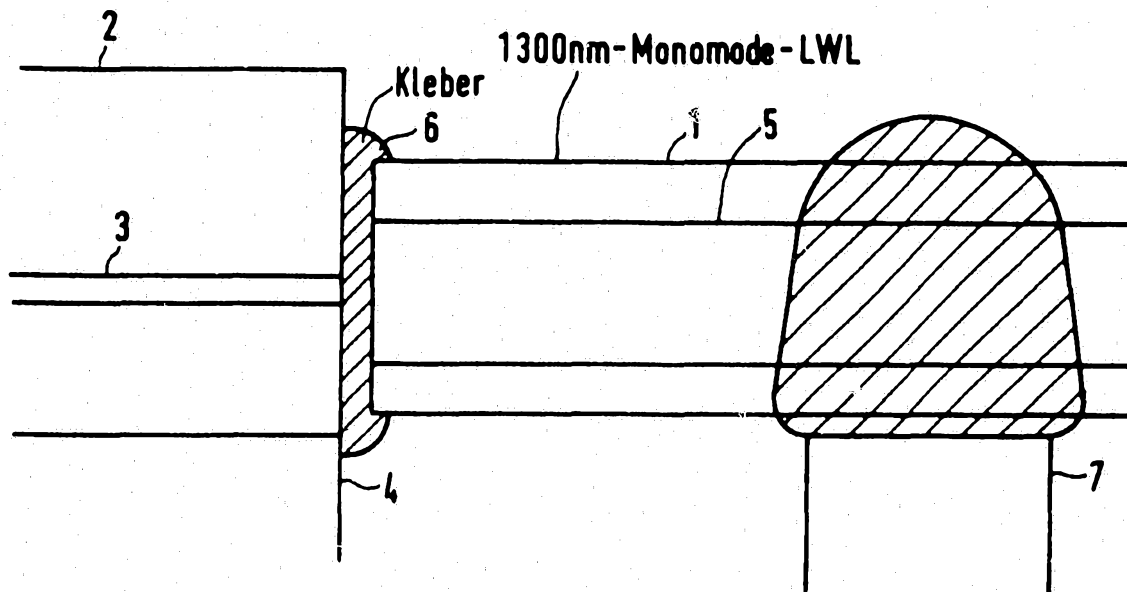


FIG. 3

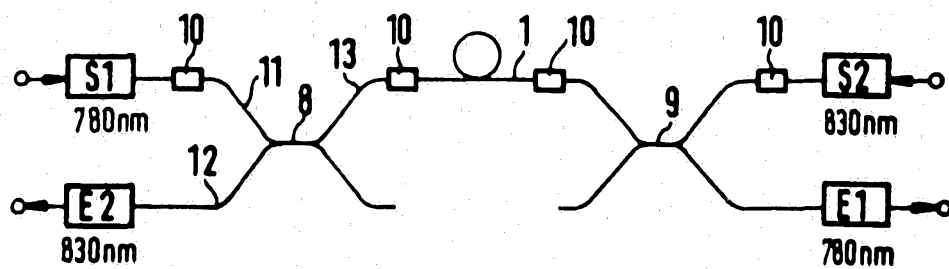


FIG. 4

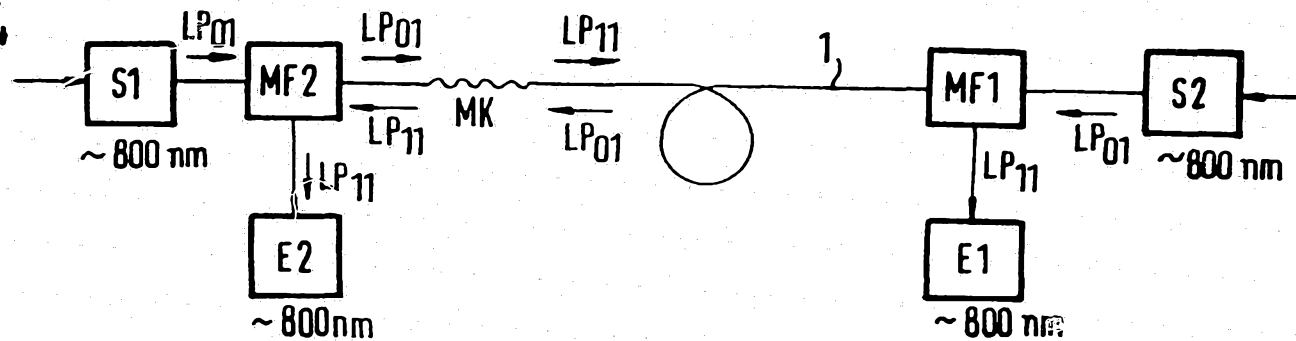


FIG. 5

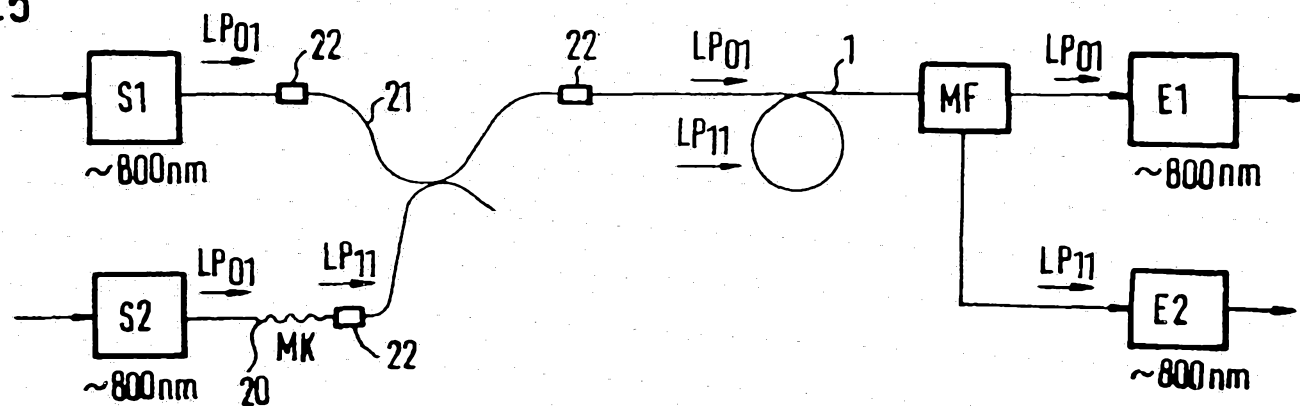


FIG. 6

