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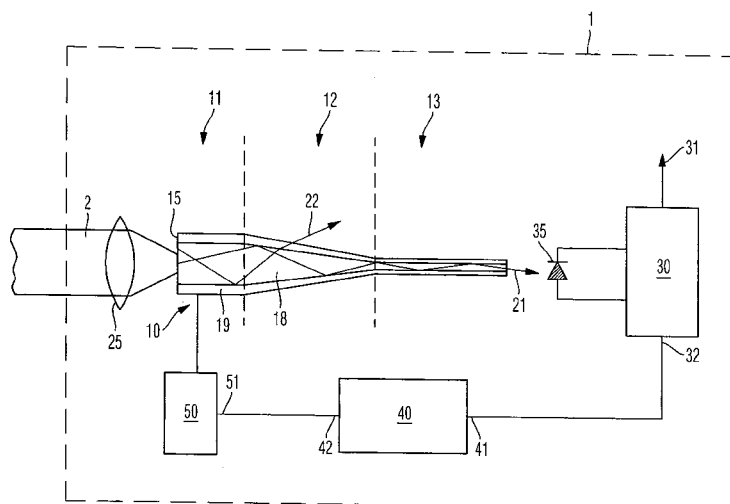


Fig. 1

(57) Abstract: The invention relates to an optical receiver comprising: An entry surface (15) being adapted to receive an optical signal (2) from a free beam, at least one optical fiber (10) being adapted to guide said optical signal (2), the optical fiber (10) comprising at least one core (18) having a first refractive index (n_1) and a cladding (19) having a second refractive index (n_2), and a first longitudinal portion (11) being adjacent to the entry surface (15), wherein the core (18) has a first diameter and a second longitudinal portion (12), longitudinally and sequentially positioned after said first longitudinal portion (11), wherein the diameter of the core (18) is decreasing from the first diameter to a second diameter, and a third longitudinal portion (13), longitudinally and sequentially positioned after said second longitudinal portion (12), wherein the core (18) has the second diameter, and feedback control (40) being adapted to control driving means (50) being adapted to nutate and/or to shift and/or to tilt the optical fiber (10) so that the optical power transmitted through the third longitudinal portion (13) of the optical fiber (10) is maximized. Furthermore, the invention relates to a method for receiving optical signals.



Optical receiver and method for receiving optical signals

FIELD OF THE INVENTION

The invention relates to a method for receiving optical signals, said method comprising: providing at least one beam of light, transmitting said beam of light as a free beam to a receiver and coupling said light to at least one optical fiber being part of said receiver, and the optical fiber comprising at least one core having a first refractive index and a cladding having a second refractive index.

Furthermore, the invention relates to an optical receiver comprising an entry surface being adapted to receive an optical signal from a free beam, at least one optical fiber being adapted to guide said optical signal, the optical fiber comprising at least one core having a first refractive index and a cladding having a second refractive index. The optical receiver comprises further a feedback control being adapted to control driving means being adapted to move or to modulate the optical fiber so that the optical power transmitted through the optical fiber is maximized.

An optical receiver and a method for receiving optical signals as detailed above may be used for optical data

transmission or in laser-based measuring or targeting systems.

BACKGROUND OF THE INVENTION

From US 2001/0005273 A1 a method and an arrangement for establishing a connection between satellites is known. The sender according to this known arrangement is adapted to send an optical signal being composed of a data signal and beacon light. An acquisition sensor is provided for acquiring the beacon light in the receiver, thereby optimizing the coupling of the optical signal to the receiver. After that optimization, the receiver is able to generate an electrical signal carrying the information of the optical data signal. The optical fiber constituting the beam entrance is movable by means of a nutator. A feedback control is provided to move the optical fiber in a position where the optical power entering the receiver is maximized.

This known receiver has the disadvantage that the range of acceptance of an optical fiber is quite narrow. Therefore, it might be difficult to establish a connection between a sender and a receiver or the data transmission might be interrupted from time to time if the beam of light directed to the receiver falls at least partly outside the acceptance range of the fiber.

Therefore, it may be an object of the invention to provide a method for receiving optical signals with improved reliability. Furthermore, it is an object of the invention to provide a receiver for optical signals being in some embodiments more reliable. Furthermore, it may be an object of the invention to provide a method and/or a receiver for receiving optical signals which may establish a connection to a sender more easily.

SUMMARY OF THE INVENTION

The object of the invention is solved by a method according to claim 1 and a receiver according to claim 10.

According to the invention, a method for receiving optical signals and a receiver for optical signals is disclosed. The method comprises at least the following steps as detailed below. The receiver comprises at least means for carrying out at least one of these functions.

First, at least one beam of light is provided by means of a sender. The sender may be included in the receiver in some embodiments. In other embodiments of the invention, the sender may be located at a remote position from the receiver. The beam of light may comprise laser light or light from a light emitting diode. The at least one beam of light may be composed of multiple components which differ from each other in their respective polarizing state and/or wavelength. A plurality of components may be used to increase the bandwidth of a system for optical data transfer by means of wavelength division multiplexing or polarization divisional multiplexing. In other embodiments of the invention, one component may be modulated in order to transmit data and another component of the beam of light may be used as beacon light to facilitate establishing the connection between the sender and the receiver. In still another embodiment of the invention, the beam of light may be unmodulated or equally pulsed and the receiver may be adapted to detect reflected light. In some embodiments, the sender of that unmodulated light may be arranged beneath the receiver. Such an embodiment of the invention is in particular useful for measuring a direction and/or a distance of an object being located remote from the receiver and reflecting at least a part of said beam of light.

The wavelength of the at least one beam of light may be selected from the infrared, the visible or the ultraviolet spectrum. In some embodiments of the invention, the wavelength may be selected from the interval ranging from 1.6 to 1.3 μm . In other embodiments of the invention, the wavelength of the beam of light may be selected from the interval ranging from 0.7 to 0.4 μm . In still another embodiment, the wavelength of the beam of light may be selected from the interval ranging from 1.6 to 0.4 μm .

The beam of light is transmitted to the receiver as a free beam. This means that at least a part of the transmission path between sender and receiver is not confined by a bounding surface such as a waveguide, but the light propagates freely.

The beam of light hits an entry surface of the receiver and is coupled to at least one optical fiber which is adapted to guide at least a part of the light inside the receiver. The optical fiber comprises at least one core having a first refractive index and a cladding having a second refractive index. The first refractive index may be greater than the second refractive index so that the light is guided inside the core and encounters total reflection on the boundary surface between the core and the cladding. Furthermore, the optical fiber may comprise an optional coating covering at least partly the outside surface of the cladding. The coating may avoid ingress of unwanted light producing noise and/or may increase the mechanical stability of the optical fiber. The coating may be made from a polymer such as polyurethane, polyvinylchloride, polyethylene or the like. The core and the cladding may be made from a polymer or a glass. Some parts may comprise a dopant in order to control the refractive index of this part.

To improve the coupling of the light into the optical fiber, the fiber comprises at least a first longitudinal portion, a

second longitudinal portion and a third longitudinal portion. The first longitudinal portion is arranged adjacent to the entry surface. The core has a first diameter along the first longitudinal portion. The diameter of the core may have a size that allows establishing a multimode optical fiber in the first longitudinal portion.

The second longitudinal portion is longitudinally and sequentially positioned after the first longitudinal portion. The diameter of the core of the optical fiber in the second longitudinal portion decreases with length of the second longitudinal portion from the first diameter to a second diameter. The second diameter is smaller than the first diameter. In some embodiments of the invention, the second diameter may have a size which allows establishing a single mode optical fiber.

The third longitudinal portion is longitudinally and sequentially positioned after said second longitudinal portion. The core has a substantially constant diameter in the third longitudinal portion. This diameter is usually but not necessarily the second diameter. The third longitudinal portion may be a single mode optical fiber in some embodiments of the invention.

Providing an optical fiber with a larger core diameter adjacent to the entry surface allows for a higher acceptance of the optical fiber. Therefore, acquiring the freely propagating beam of light may become easier as tolerances in spatial movement increase. However, the optical fiber may acquire unwanted optical modes as well. This unwanted light may be removed from the optical fiber when propagating along the second longitudinal portion because the number of propagating modes decreases with the core diameter along the length of the second longitudinal portion, thereby emitting unwanted modes of light from the optical fiber. Furthermore, during propagation along the second longitudinal portion,

the diameter of the basic mode being intended to propagate in the third longitudinal portion may be reduced from the diameter of the entry surface to the final diameter of the third longitudinal portion.

The optical receiver may further comprise driving means being adapted to nutate and/or to shift and/or to tilt at least a part of the optical fiber including the entry surface. In some embodiments, said driving means are under control of a feedback control so that the entry surface of the receiver may be moved relative to the beam of light such that coupling of the light is improved and or kept constant. In some embodiments, the feedback control may be adapted to optimize the optical power of a basic mode in the thoird longitudinal portion.

In some embodiments of the invention, the feedback control may comprise a proportional controller, a proportional plus integral controller, a proportional plus derivative controller or a proportional plus integral plus derivative controller. In some embodiments of the invention, the feedback control may comprise any of at least one operational amplifier or a digital signal processor or a microcontroller and a software implementing the feedback control if the software is executed on the microcontroller.

In some embodiments of the invention, the receiver may comprise further a focusing optics being adapted to focus the beam of light onto the entry surface. Such an embodiment of the invention may provide the advantage that a broader range of acceptance may be provided to acquire the beam of light. In some embodiments, the refraction power of the focusing optics may be reduced compared to known optical receivers as the size of the entry surface is larger and thus, less demagnification of the cross section of the free beam may be needed.

In some embodiments of the invention, the numerical aperture is substantially constant in the first, second and third longitudinal portions of the optical fiber. The numerical aperture N.A. is defined by the following formula

$$\text{N.A.} = \sin(\theta_0) = \sqrt{n_1^2 + n_2^2} ,$$

wherein θ_0 defines the maximum angle of acceptance of the optical fiber and n_1 and n_2 describe the refractive index of the core and the cladding, respectively.

In some embodiments of the invention, the first diameter is 3 to 7 times larger than the second diameter. Thus, the acceptance of the receiver's entrance may be 3 to 7 times better compared to known receivers using conventional optical fibers. In some embodiments of the invention, the first diameter is selected from approximately 30 μm up to approximately 100 μm . Accordingly, the second diameter is selected from approximately 5 μm up to approximately 15 μm .

In some embodiments of the invention, the driving means may comprise a nutator being adapted to nutate the at least one optical fiber. Nutating the fiber may comprise a random or periodic movement of the fiber until a first signal is acquired from the beam of light entering the entry surface. If a first signal has been acquired, the movement of the nutator may be under control of the feedback control in order to maximize the optical power transmitted through the third longitudinal portion of the optical fiber.

Optimization on the optical power transmitted through the third longitudinal portion ensures that the signal carrying user data reaches the receiver or a demodulator being part of said receiver in the best possible way. Other optical signals may be lost in the second longitudinal portion of the optical fiber to reduce background noise.

In some embodiments of the invention, the receiver may comprise a plurality of optical fibers each having a respective entry surface. The provision of a plurality of fibers being arranged substantially parallel to each other may increase the entry surface further. This may allow an easier acquisition of a first signal so that a connection for data transfer may be established more easily or a range finder may have a broader range of acceptance.

In some embodiments of the invention, the number of fibers may be selected from 4 up to 20 or the number of fibers may be selected from 5 to 15.

In some embodiments of the invention, the plurality of fibers has a circular arrangement with at least one first fiber being located on a central axis and the remaining fibers surrounding said first fiber. In such an arrangement, the first fiber may be used to guide a data signal to a decoder wherein the outer fibers of the arrangement may be used to sense the position of the incoming beam of light so that the feedback control is able to tilt and/or shift the plurality of fibers such that a first contact may be made faster or the data connection may be more reliable.

In some embodiments of the invention, the second longitudinal portion has a length being selected from approximately 5 mm up to approximately 20 mm. This will minimize optical losses of the at least one mode being transferred to the third longitudinal portion and sufficiently suppress other modes.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing aspects and many of the attendant advantages of this invention will become more readily appreciated as the same becomes better understood by reference to the

following detailed description, when taken in conjunction with the accompanying drawings, wherein:

Fig. 1 illustrates a first embodiment of a receiver according to the invention.

Fig. 2 illustrates a second embodiment of a receiver according to the invention.

Fig. 3 illustrates the entry surface according to the second embodiment in greater detail.

Fig. 4 illustrates a first embodiment of an optical fiber being usable with the invention.

Fig. 5 illustrates a second embodiment of an optical fiber being usable with the invention.

Fig. 6 illustrates the improvement in signal quality.

DETAILED DESCRIPTION

Fig. 1 illustrates aspects of the invention on the basis of a first embodiment of a receiver. The receiver is generally denoted with reference number 1. The receiver 1 is adapted to receive a beam of light 2. The beam of light 2 may be unmodulated like laser light from a laser range finder. In other embodiments of the invention, the beam of light 2 may comprise at least one component that is modulated to represent user data. A plurality of data signals may be encoded in the beam of light by using different polarization states or different wavelengths as a carrier signal for the different data streams.

The beam of light 2 may be focused by means of a focusing optics 25 on the entry surface 15. The focusing optics 25 is shown as a single collimating lens. However, it should be

clear that other optical elements such as a mirror may be used as well and that the focusing optics 25 may be composed of a plurality of different optical elements such as a plurality of lenses and/or mirrors. It has to be pointed out that the focusing optics 25 is optional and may be omitted in other embodiments of the invention.

The light arriving directly or through the focusing optics 25 on the entry surface 15 of waveguide 10 is coupled into the core 18 of the waveguide 10. The core 18 has a slightly larger refractive index n_1 compared to the cladding 19 surrounding said core 18 and having a smaller refractive index n_2 . Therefore, light being coupled into the core 18 of the optical fiber 10 will be totally reflected on the bordering surface between the core 18 and the cladding 19, so that the light propagates along the length of the waveguide 10.

The waveguide 10 may be made from a polymer or a glass. The difference in refractive index between the core 18 and the cladding 19 may be obtained in different embodiments of the invention by doping either the core or the cladding or both, using different polymeric materials for the cladding and the core or by material modification by means of laser radiation.

As can be seen from Fig. 1, the optical fiber 10 has a first longitudinal portion 11, a second longitudinal portion 12 and a third longitudinal portion 13. In the first longitudinal portion 11, the core 18 has a first diameter. In the third longitudinal portion the core 18 has a second diameter. In both the first and the third longitudinal portion, the diameter of the core is substantially constant. In the bridging second longitudinal portion 12, the core decreases from its first diameter to the second diameter. Decreasing of the core may be done linearly with length or with a non-linear function, i.e. quadratic or cubic.

Optimization of the shape and length of the core 18 in the second longitudinal portion 12 may be done by means of computer analysis with ray tracing programs.

Fig. 1 shows two exemplary modes. The first mode 21 is transmitted from the entry surface 15 via the first and second longitudinal portions 11 and 12 into the third longitudinal portion 13. The second mode 22 is transmitted from the entry surface 15 via the first longitudinal portion 11 into the second longitudinal portion 12. As the core diameter decreases, the second mode 22 is coupled out of the core 18 and is able to leave the waveguide 10. In some embodiments of the invention, the third longitudinal portion 13 may comprise a single mode waveguide so that all other modes except a predefined mode coupled into the waveguide 10 may be removed along the second longitudinal portion 12. To effectively filter these modes, the second longitudinal portion 12 may have a length ranging from 5 mm up to 20 mm. Nevertheless, the large diameter of the core 18 at the entry surface 15 ensures effective coupling of the incoming beam of light 2 into the core 18.

In the exemplary embodiment shown in Fig. 1, the receiver 1 is adapted to establish a wireless data communication. This means that the beam 2 of light comprises at least one first mode 21 carrying user data. The first mode 21 is guided by means of the third portion 13 of the waveguide 10 to a photodiode 35. In some embodiments of the invention, the photodiode 35 may be embodied as a waveguide integrated photodiode and the third longitudinal portion 13 may be part of a chip integrated waveguide. It has to be pointed out that the single photodiode 35 is only exemplary and may be replaced by any other means for conversion of an optical signal into an electric signal, such as a pn-diode, a pin-diodes, a phototransistor, a photoresistor or a plurality of these known elements.

The photodiode 35 is connected to a demodulator 30. The demodulator 30 provides a balancing voltage or a bias voltage to the photodiode 35 and reads the electrical signals generated by the photodiode 35. The demodulator 30 may decode a data stream received and may be adapted to restore user data.

The decoder 30 has a first output 31 providing user data to other circuitry. The first output 31 may be an optical or an electrical digital output or an analog output providing a voltage representing the user data.

Furthermore, the decoder 30 has at least one second output 32. The second output 32 carries an analog or digital data signal being indicative of the optical power of the first mode 21 reaching the photodiode 35. The data signal of the output 32 of the decoder 30 is supplied to the first input 41 of a feedback control 40.

The feedback control 40 may be of any kind known from the art such as a PD-controller, a P-controller, a PI-controller or a PID-controller. The feedback control 40 may be embodied as a hardware or as a software, i.e. the feedback control 40 may comprise any of an operational amplifier, a DSP, or a microcontroller and a software implementing the function of the feedback control. The feedback control 40 has an output 42 which is coupled to an input 51 of a nutator 50. The nutator 50 is adapted to swivel, tilt, nutate, and/or shift at least a part of the first longitudinal portion 11 of the waveguide 10 so that the angle and the position of the entry surface 15 may be moved towards or aligned to the beam of light 2. A decreasing optical power of the first mode 21 will lead to a movement of the entry surface 15 so that the optical power delivered to the photodiode 35 is maximized. This may establish a more reliable data connection, i.e. the bit error rate may decrease or the speed of data transmission may increase.

With respect to fig. 2, aspects of the invention are explained on the basis of a second embodiment of a receiver. Equal parts are denoted with same reference numbers so that the following description will be restricted to the main differences. Fig. 2 shows a decoder 13 and a feedback control 40 as detailed previously. The output 42 of the feedback control 40 may be coupled to a nutator not shown in Fig. 2.

The main difference between the first and the second embodiment relates to the number of optical fibers. As can be seen from Fig. 2, the receiver comprises a first or central fiber 10a which is surrounded by outer fibers 10d and 10g. The fiber arrangement is shown in a cross-sectional view in Fig. 2 and the front side is illustrated in Fig. 3. As can best be seen in Fig. 3, the receiver comprises seven optical fibers in such a circular arrangement having a first fiber 10a and 6 outer fibers 10b, 10c, 10d, 10e, 10f, and 10g.

Every optical fiber comprises a first, a second and a third longitudinal portion as detailed with respect to Fig. 1. In other embodiments of the invention, the outer optical fibers 10b, 10c, 10d, 10e, 10f and 10g may be of a conventional straight type. One end of the optical fibers constitutes the entry surface 15. The opposing ends of the optical fibers are coupled with a respective photodetector 35. At least the photodetector 35a of the central fiber 10a is coupled to the decoding unit 30 in order to provide a data signal on its output 31. The remaining photodetectors are coupled to the feedback control 40 to improve the alignment of the entry surface 15 with the beam light 2.

During operation of the receiver according to this second embodiment of the invention, the outer fibers 10b to 10g may detect the presence of the beam of light 2. This information is supplied to the feedback control 40 and the fiber nutator

is operated such that the intensity detected by the outer photodetectors 35a to 35g is equalized and/or minimized and the optical power transfer to the central fiber 10a is maximized. This means that the beam of light 2 hits the entry surface 15 central.

It has to be noted that the provision of seven optical fibers is only an exemplary embodiment of the invention. In other embodiments of the invention, the number of fibers may be smaller or even larger. In still other embodiments of the invention, the optical fibers may be arranged in several concentric rings so that the orientation and alignment of the entry surface 15 may be improved further.

With respect to fig. 4, aspects of the invention are explained on the basis of a first embodiment of an optical fiber being operable in conjunction with the receivers 1 explained above. The optical fiber 10 comprises a core 18 with an approximately circular cross-section. The core 18 is surrounded by a substantially cylindrical cladding 19. The core is made from a material with a first refractive index n_1 and the cladding is made from a material with a second refractive index n_2 . The second refractive index is usually smaller than the first refractive index so that total reflection of optical modes occurs at the boundary surface between the core 18 and the cladding 19. The cladding 19 is surrounded by an optional coating 17 which may prevent the ingress of parasitic light and/or improve the mechanical protection of optical fiber 10. In some embodiments of the invention, the core 18 and the cladding 19 may be made from a glass or a polymer and the coating 17 may comprise a polymeric coating such as polyvinylchloride.

The cladding 19 and the optional coating 17 has a substantially cylindrical shape. In order to provide first, second and third longitudinal portions of the waveguide, the diameter of the core 18 is varying with the length of the

waveguide. This means that in the first portion 11 the core 18 has a first diameter, and the third longitudinal portion 13 in the core 18 has a second diameter and in the bridging second longitudinal portion 12 the core diameter is reduced from the first to the second diameter.

The waveguide according to Fig. 4 may be produced by material modification by means of laser radiation. The laser light may alter the refractive index of the cladding 19 of a conventional optical fiber having the constant cross-section of the third longitudinal portion 13. This may lead to the formation of a first and a second longitudinal portion in such a conventional waveguide as parts of the cladding are modified to increase the core diameter.

Fig. 5 is used to explain aspects of the invention with respect to a second embodiment of an optical fiber 10 being usable for a receiver 1 as explained with respect to figures 1, 2, and 3. The optical fiber according to Fig. 5 comprises a core 18, a cladding 19, and a coating 17 as detailed above. The relationship of the diameters of the core, the cladding and the coating remain constant in all longitudinal portions of the optical fiber. However, the absolute values of the diameters are changing from the first longitudinal portion 11 to the third longitudinal portion 13. Therefore, the outer diameter of the first longitudinal portion 11 is larger than the outer diameter of the third longitudinal portion 13 and the second longitudinal portion 12 has a shape of a cone. Manufacturing of the optical fiber may be done by starting with an optical fiber having the cross-section of the first longitudinal portion 11 and drawing the optical fiber in a conventional way by means of a wire drawing die to decrease its total diameter.

Fig. 6 illustrates the optical losses in dB on the ordinate Y and the beam distance from the center of the optical fiber 10 or 10a in micrometers on the abscissa X. Line A gives

values of the optical losses for a conventional optical single mode fiber with constant cross-section. Line B indicates the optical losses for an optical fiber according to the invention having a third longitudinal portion constituting a single mode fiber. It can be seen from Fig. 6 that the optical losses are decreasing dramatically. As an example, for a misalignment of 20 μm , the optical losses of a known fiber amount 30 dB, whereas the optical losses using a fiber according to the invention amount less than 3 dB. This means that optical data communication will be possible at low bit error rates even if a large misalignment between the optical fiber and the beam of light occurs. In some embodiments of the invention, reduced optical losses may increase the input signal of a feedback control which may result in a better alignment of the optical fiber.

The illustrative embodiments and modifications thereto described hereinabove are merely exemplary. It is understood that other modifications to the illustrative embodiments will readily occur to persons of ordinary skill in the art. All such modifications and variations are deemed to be within the scope and spirit of the present invention as will be defined in the accompanying claims. The above described embodiments may be used alone or combined for use.

Claims

1. A method for receiving optical signals, said method comprising:
 - Providing at least one beam of light (2),
 - Transmitting said light as a free beam to a receiver (1),
 - Coupling said light to at least one optical fiber (10) being part of said receiver (1),
 - wherein
 - the optical fiber (10) comprises at least one core (18) having a first refractive index (n_1) and a cladding (19) having a second refractive index (n_2), and
 - a first longitudinal portion (11) being adjacent to an entry surface (15), wherein the core (18) has a first diameter and
 - a second longitudinal portion (12), longitudinally and sequentially positioned after said first longitudinal portion (11), wherein the diameter of the core (18) is decreasing from the first diameter to a second diameter,
 - a third longitudinal portion (13), longitudinally and sequentially positioned after said second longitudinal portion (12), wherein the core (18) has the second diameter.
2. Method according to claim 1, wherein a single optical mode (21) is guided in said third longitudinal portion (13).
3. Method according to any of claims 1 or 2, wherein the beam of light (2) is focused onto the entry surface (15).
4. Method according to any of claims 1 or 3, wherein the numerical aperture is substantially constant in the first, second and third longitudinal portions (11, 12, 13).

5. Method according to any of claims 1 to 4, wherein the first diameter is 3 to 7 times larger than the second diameter.
6. Method according to any of claims 1 to 5, wherein the at least one optical fiber (10) nutates.
7. Method according to any of claims 1 to 6, wherein the light is coupled to a plurality of optical fibers (10a, 10b, 10c, 10d, 10e, 10f, 10g) each having a respective entry surface (15).
8. Method according to claim 7, wherein said beam of light (2) is at least partly modulated to transmit data and the plurality of fibers (10) is moved so that the optical power received by the outer fibers (10b, 10c, 10d, 10e, 10f, 10g) is minimized and the optical power received by a central fiber (10a) is maximized.
9. Method according to any of claims 1 to 8, wherein a plurality of optical modes (21, 22) is coupled to the entry surface (15) of the first longitudinal portion (11) of the optical fiber (10) and all modes (22) except a single mode (21) are removed from the optical fiber (10) when the optical signal travels along the second longitudinal portion (12).
10. An optical receiver comprising:
 - An entry surface (15) being adapted to receive an optical signal (2) from a free beam,
 - At least one optical fiber (10) being adapted to guide said optical signal (2), the optical fiber (10) comprising at least one core (18) having a first refractive index (n_1) and a cladding (19) having a second refractive index (n_2), and a first longitudinal portion (11) being adjacent to the entry surface (15), wherein the core (18) has a first diameter and a second longitudinal portion (12), longitudinally and sequentially positioned after said first longitudinal

portion (11), wherein the diameter of the core (18) is decreasing from the first diameter to a second diameter, and a third longitudinal portion (13), longitudinally and sequentially positioned after said second longitudinal portion (12), wherein the core (18) has the second diameter,

A feedback control (40) being adapted to control driving means (50) being adapted to nutate and/or to shift and/or to tilt the optical fiber (10) so that the optical power transmitted through the third longitudinal portion (13) of the optical fiber (10) is maximized.

11. Receiver according to 10, comprising further a focusing optics (25) being adapted to focus the beam of light (2) onto the entry surface (15).
12. Receiver according to any of claims 10 or 11, wherein the numerical aperture is substantially constant in the first, second and third longitudinal portions (11, 12, 13) of the optical fiber (10).
13. Receiver according to any of claims 10 to 12, wherein the first diameter is 3 to 7 times larger than the second diameter.
14. Receiver according to any of claims 10 to 13, wherein the first diameter is selected from 30 μm up to 100 μm .
15. Receiver according to any of claims 10 to 14, wherein the driving means (50) comprise a nutator being adapted to nutate the at least one optical fiber (10).
16. Receiver according to any of claims 10 to 15, comprising a plurality of optical fibers (10a, 10b, 10c, 10d, 10e, 10f, 10g) having a respective entry surface (15) being adapted to receive said beam of light (2).
17. Receiver according to claim 16, wherein the number of fibers is selected from 4 to 15

18. Receiver according to any of claims 16 to 17, wherein the plurality of fibers (10a, 10b, 10c, 10d, 10e, 10f, 10g) has a circular arrangement with a first fiber (10a) being located on a central axis and the remaining fibers (10b, 10c, 10d, 10e, 10f, 10g) surrounding said first fiber (10a).
19. Receiver according to any of claims 10 to 18, wherein the second longitudinal portion (12) has a length selected from 5 mm up to 20 mm

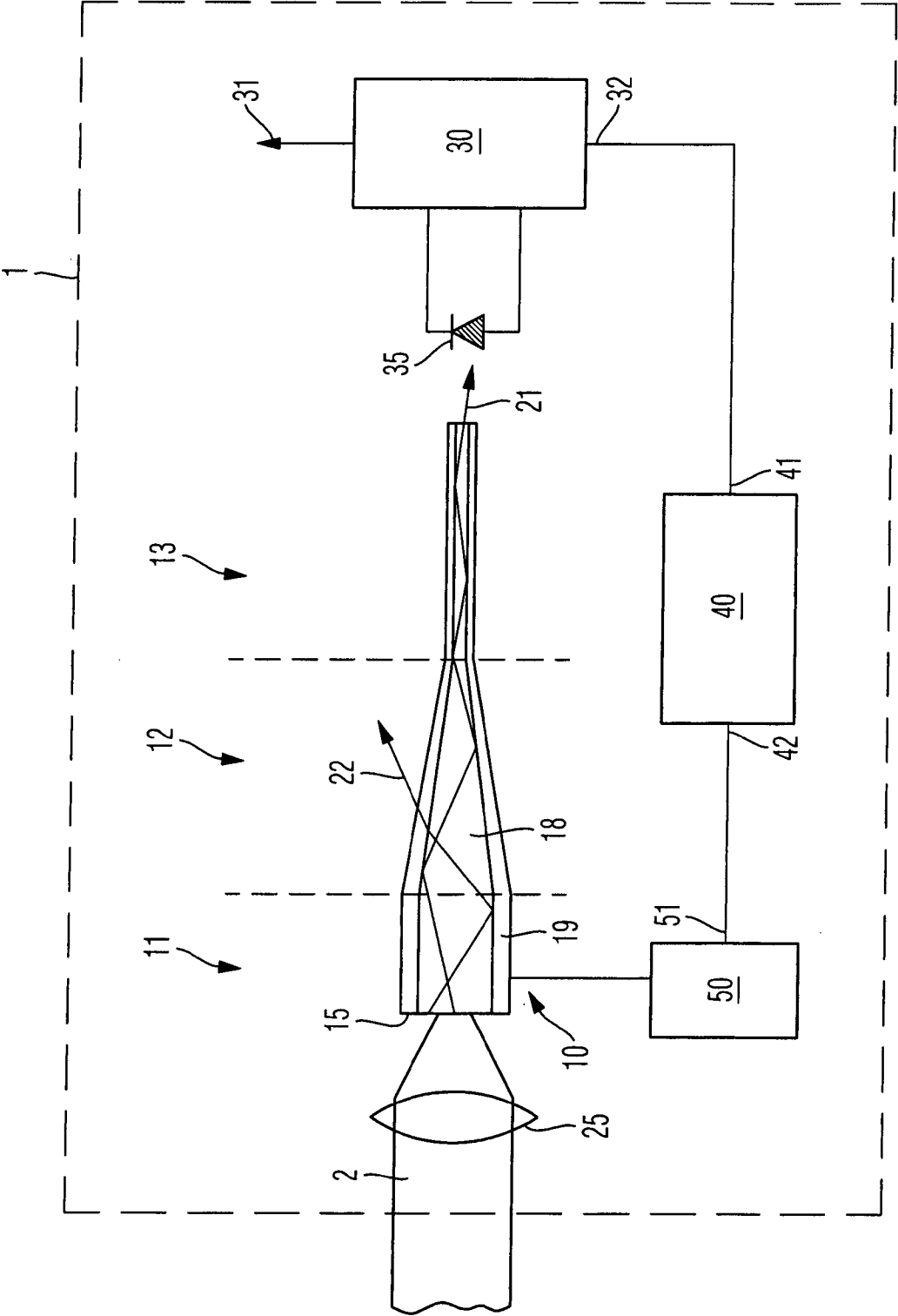


Fig. 1

2/3

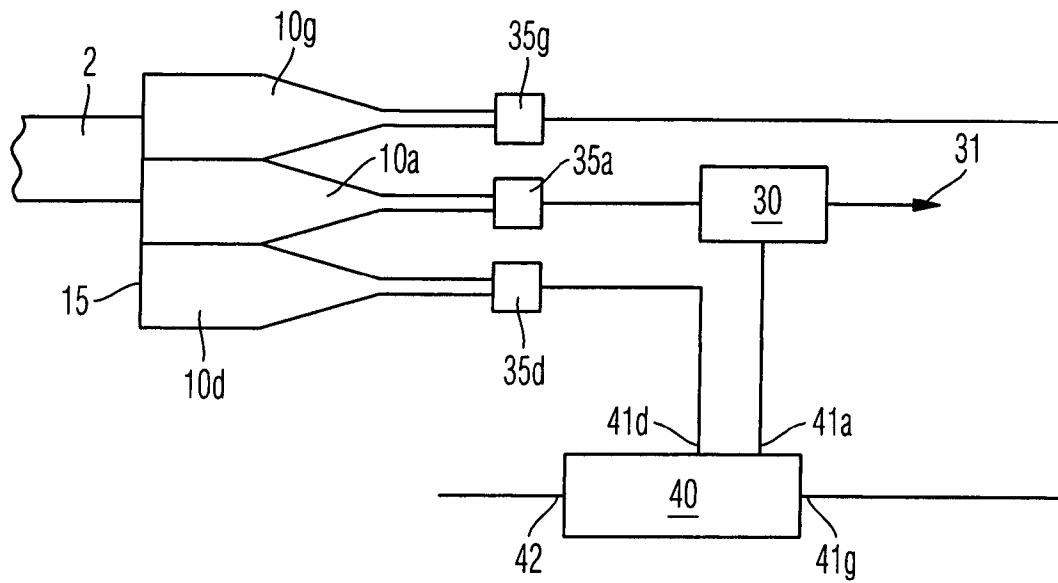


Fig. 2

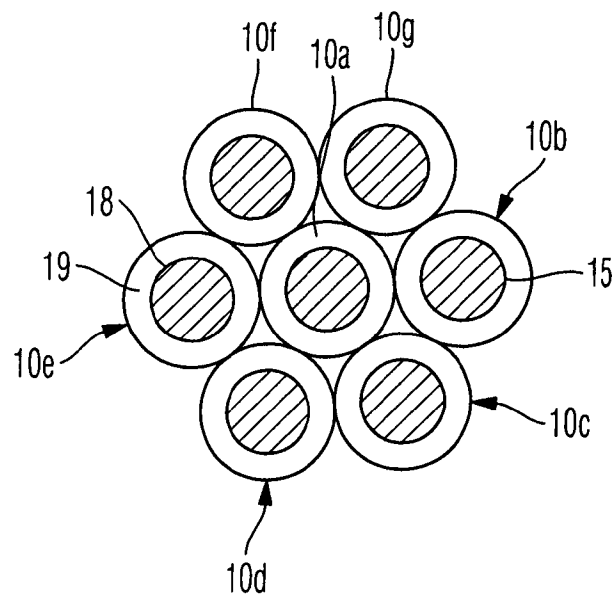


Fig. 3

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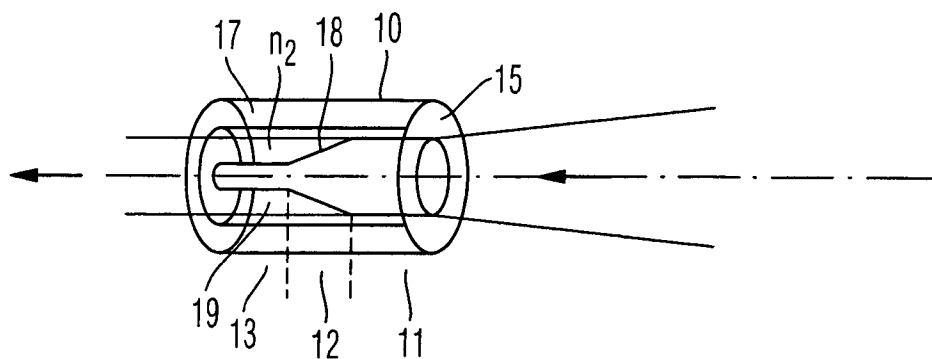


Fig. 4

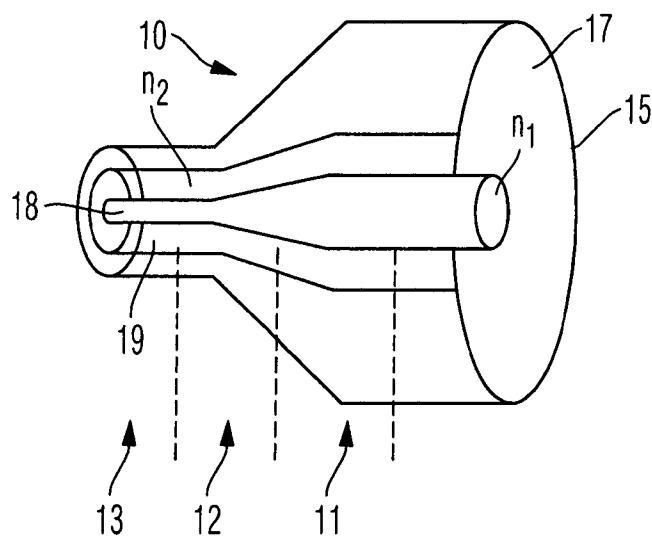


Fig. 5

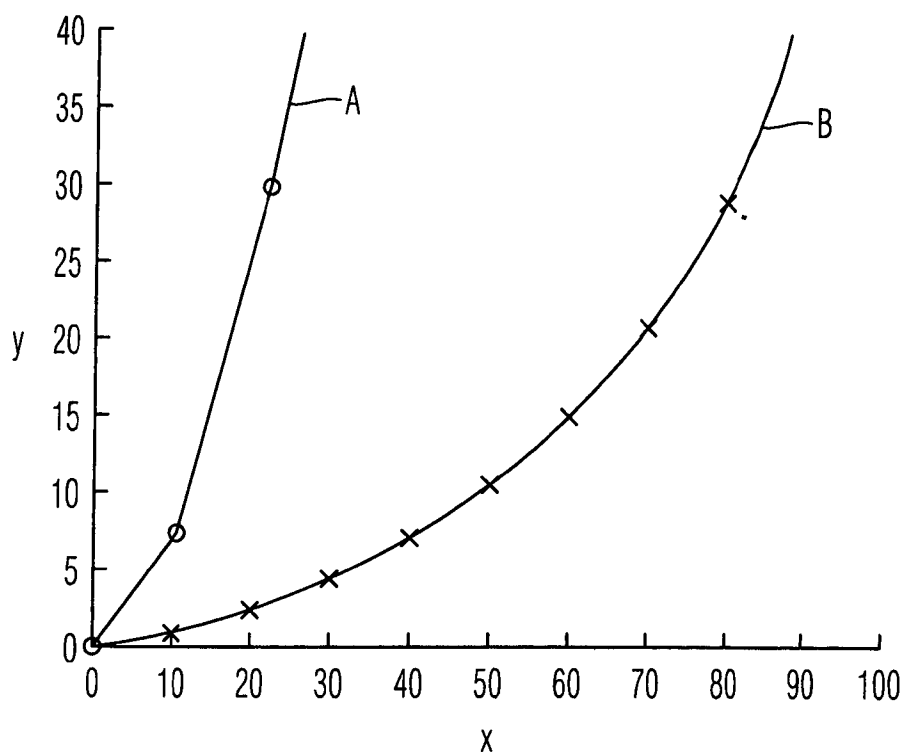


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/074341

A. CLASSIFICATION OF SUBJECT MATTER INV. G02B27/09 G02B6/26 G02B6/42 H04B10/11 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) G02B H04B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012/008961 A1 (CHEN YOUNG-KAI [US] ET AL) 12 January 2012 (2012-01-12)	1-4,7-9, 17,19
Y	paragraphs [0001], [0024] - [0034]; figures 3,4	6,10-12, 15,16,18

X	EP 1 418 689 A2 (CIT ALCATEL [FR] ALCATEL LUCENT [FR]) 12 May 2004 (2004-05-12)	1,3-5, 17,19
Y	paragraphs [0001], [0028] - [0036]; figures 1,2	6,10, 12-15

Y	US 5 062 150 A (SWANSON ERIC A [US] ET AL) 29 October 1991 (1991-10-29)	6,10-16, 18
A	column 6, lines 47-62; figure 3 column 7, lines 38-63	1

A	US 5 192 863 A (KAVEHRAD MOHSEN [CA] ET AL) 9 March 1993 (1993-03-09)	1,10
column 1, lines 9-15; figure 5		

-/-		
☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
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"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family	
Date of the actual completion of the international search 9 April 2013	Date of mailing of the international search report 19/04/2013	
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Verdrager, Véronique	

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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A	US 4 521 070 A (SOTTINI STEFANO [IT] ET AL) 4 June 1985 (1985-06-04) column 3, line 62 - column 4, line 29; figure 1 -----	1,10
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