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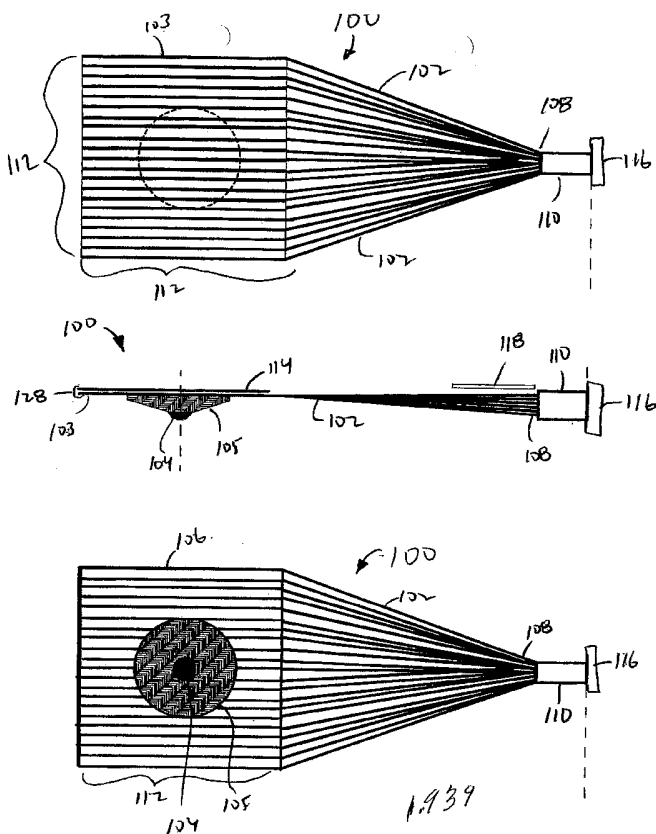
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(54) Title: LOW PROFILE FIBER OPTIC VITAL SIGNS SENSOR



(57) Abstract: The present invention provides a low profile fiber optic sensor including a fiber optic fan having a collecting end with a light-collecting portion, a terminal end, a core material extending from the collecting end to the terminal end and an outer cladding. The fiber optic fan may be made from a plurality of optical fibers or a light pipe. The light-collecting portion is formed into a pattern that has a shape with a first side and a second side. A light source is positioned on the first side of the pattern with an opaque light shield positioned about the light source. To enhance the performance of the sensor, an optical lens is coupled to the core material on the first side of the pattern to enhance detection of the light. The lens may be an array of micropisms, spheres or hemispheres.



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LOW PROFILE FIBER OPTIC VITAL SIGNS SENSOR

Priority is claimed to US Provisional application 60/488,869, filed July 21, 2003 for "Low Profile Fiber Optic Vital Signs Sensor".

FIELD OF THE INVENTION

This invention is generally related to an optical vital signs sensor, specifically to a low profile fiber optic sensor using optical reflectance techniques, and more specifically to a low profile fiber optic sensor having optical enhancements to improve detection of the optical reflectance.

BACKGROUND OF THE INVENTION

Pulse oximeters for measuring blood oxygenation have been developed using both transmission and reflectance approaches. Transmission oximeters use optical methods to determine blood oxygen saturation by transmitting light through a patient's appendage, such as a finger or an earlobe. By comparing the characteristics of the light transmitted into one side of the appendage with that detected on the opposite side, it is possible to compute oxygen concentrations. The main disadvantage of transmission oximetry is that it can only be used on portions of the body that are thin enough to allow passage of light.

Reflectance oximeters operate by shining light into the tissue and using reflected light being modulated by pulsing blood to measure blood oxygen saturation. A reflectance oximeter would be especially useful for measuring blood oxygen saturation in portions of a patient's body that are not well suited to transmission measurements. One of the difficulties with previous reflectance oximeters, however, is they are bulky and stiff and are difficult to affix to the skin. In addition, the surface area of the sensor in contact with the skin is usually small and incapable for receiving adequate amount of reflected light in areas of the body having low blood perfusion. Finally, the height of the reflectance oximeters is too high when affixed to the skin to comfortably wear under cloths.

It would be advantageous to develop a reflectance sensor that is relatively flat and flexible so that the sensor can conform to the shape of the body part. It would further be advantageous if the sensor had improved detection performance.

SUMMARY OF THE INVENTION

The invention advantageously addresses the needs and drawbacks of previous sensors as well as other needs by providing a conformal, low profile sensor for measuring and monitoring vital signs of patients through optical reflectance.

In one embodiment, the invention provides a low profile fiber optic sensor having a fiber optic fan with a light collection portion and a light-emitting device near a center of the light-collecting portion. The fiber optic fan may be made from a plurality of optical fibers having a light-collecting end and a terminal end with an outer cladding. In another embodiment, the fiber optic fan is made from a plate light pipe. The light-emitting device is a bi-color light-emitting diode (LED) able to generate pulsed illumination at two predefined spectra, for example, 660 nm (red spectra) and at 940 nm (near infrared spectra). The light collection portion may be a flat pattern such that light that is emitted from the light source is reflected back and received in the light collection portion, where it goes through the outer cladding and into the core and travels to the terminal end. The terminal end may include a detector.

In other embodiments, the outer cladding in the light collection portion may be removed from the optical fibers so that the light may enter the core directly, without going through the outer cladding. An optical lens may be attached over the core in the light collection portion to enhance the reception of optical light by the core. The optical lens may be an array of microprisms, spheres or hemispheres.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A-1C show a low profile fiber optic sensor according to one embodiment of the invention.

Fig. 2 shows a cross-sectional view of the low profile fiber optic sensor embodiment similar to Fig. 1 showing the removal of some outer cladding to enhance the amount of reflected light detected.

Figs. 3A-3D show a low profile fiber optic sensor according to another embodiment of the invention having spherical or hemispherical lenses to further enhance the amount of reflected light detected.

Figs. 4A-4C show a low profile fiber optic sensor according to another embodiment of the invention having hemispherical lenses to further enhance the amount of reflected light detected.

Figs. 5A-5D show a low profile fiber optic sensor according to another embodiment of the invention having a lens array of microprisms to further enhance the amount of reflected light detected.

Figs. 6A-6E show a low profile fiber optic sensor according to another embodiment of the invention having a lens array of microprisms to further enhance the amount of reflected light detected.

Figs. 7A-7B show a low profile fiber optic sensor according to another embodiment of the invention having spheres attached to the input end of the optical fiber to enhance the amount of reflected light detected.

DETAILED DESCRIPTION OF THE INVENTION

The following description is not to be taken in a limiting sense, but is made merely for the purpose of describing the general principles of the invention. The scope of the invention should be determined with reference to the claims.

The present invention discloses a low profile fiber optic sensor for use with systems that measure and/or monitor patient vital signs utilizing optical signal

reflectance. Examples of some of the vital signs that can be measured by optical signal reflectance include blood oxygen saturation (SpO₂) and heart rate. Measurement is done by first illuminating the surface and subcutaneous area of the skin. The optical signal is then measured as it is reflected and modulated by the tissue, blood and/or arterial blood flow. One such system is disclosed in co-pending provisional patent application serial number _____, titled "OPTICAL VITAL SIGNS MONITOR" filed by the applicant on even date herewith, which is hereby incorporated in its entirety by this reference. The low profile fiber optic sensor disclosed is usually used with a data acquisition system. One such system is disclosed in co-pending provisional patent application serial number _____, titled "ADVANCED DATA ACQUISITION SYSTEM" filed by the applicant on even date herewith, which is hereby incorporated in its entirety by this reference.

The present invention provides a sensor that can be used to make reflective measurements when placed on the subject being monitored, for example on the chest, back, arm, leg, hand, head or substantially any other part of the patient's or subject's body. These vital sign measurements can be particularly important in determining the current health of a subject. By providing an immediate indication of these parameters, attending medical personnel are able to accurately determine the health status of the patient or subject. For example, in the case of neonatal births, determination of these vital signs becomes even more important, particularly in instances where immediate resuscitation is required to normalize the infant's life sustaining functions. The present invention can be employed as a spot check device or provide continuous monitoring of a subject. The present invention has numerous applications, including applications in hospital delivery rooms, in emergency medicine, intensive care units, home health monitoring of infants and the elderly and several other applications.

In order to achieve a low profile conformable sensor, light illumination of the skin must emanate at the skin surface and light reflected from the skin must enter the sensor and be bent quickly at an angle, so that the sensor may be low profile and lay substantially parallel to the skin surface. The present invention discloses a conformable

low profile sensor that includes the use of a fiber optic “fan” for receiving the reflected light from the skin. In some embodiments, the fiber optic “fan” contains many optical fibers sized to optimize the sensor. In one example, a fiber optic “fan” may contain fibers laid in a parallel arraignment forming a pattern in a collection area to receive the reflected light. Since the fibers are discrete, the fiber ends away from the collection area can be gathered into a “ponytail” with a circular cross-section suitable for connection to a detector or an “extension cord” leading to a detector. In other embodiments, the fiber optic “fan” may be a “plate light pipe” designed to receive the reflected light similar to the discrete fiber embodiment. In most of the embodiments presented herein, the reflected light enters the side of the fiber optic fan in the light-collecting area and travels down a core material to a detector. Commonly, the optical fibers are designed to transmit light through a core material with a specific index of refraction covered by an outer cladding having a different refractive index. In the simplest embodiment, one end of the fibers are laid in parallel on their sides to form a collection area pattern. The reflected light being transmitting through the outer cladding of the fiber and entering the core material, which carries the light to the detector.

Other embodiments disclose the removal of a small portion of the outer cladding in the light collection area, allowing light to be received directly by the core material. This allows more of the reflected light to enter the optical fiber. The remaining portion of the outer cladding performs its usual function of keeping the light inside, propagating it to the fiber ends. The missing cladding also allows some of the light that enters the fiber to escape, so the fiber is sometimes called “leaky”. A critical aspect of the design is the width of the strip of missing outer cladding, balanced between letting too little light into the fiber (narrow stripe) and letting too much light escape (wide stripe). Another consideration in the sensor design is that the light should enter the core of the fiber at an angle to allow the light to propagate inside the fiber. Since the optical fibers are designed for light to enter at the ends, the appropriate or critical angle should be as close to the fiber axis as possible. If the light enters correctly, there is a total internal reflection when it encounters the cladding on the far side and it bounces along to the fiber to its end. If the light enters perpendicular to the fiber axis, or at a large angle to the axis, the light might continue through the fiber and exit the on the far side of the fiber or reflect

on the far side cladding and exit where it entered. In order to achieve the critical angle criteria and capture a more substantial portion of reflected light, an array of lenses may be used. Their purpose is simply to bend the light reflected from the skin in the direction of the fiber axis, so that more of the light rays are within the critical angle. These lenses may include spheres, hemispheres, prisms or other shapes that are capable of re-directing or bending the reflected light path. These and other embodiments are described in more detail below.

Figs. 1A-1C show a low profile fiber optic sensor 100 according to one embodiment of the present invention. The sensor 100 includes a plurality of optical fibers 102 comprising the fiber optic fan and one or more light-emitting devices or sources 104. The light-emitting device 104 is a bi-color light-emitting diode (LED) that is activated to generate pulsed illumination at two predefined spectra. For example, the LED 104 can be configured to generate pulsed illumination at a first spectra of about 660 nm (red spectra) and at a second spectra of about 940 nm (near infrared spectra). However, illumination sources of virtually any spectral output can be used to make noninvasive optical measurements on patients or subjects. Typically, the light-emitting device 104 is centrally positioned near a center of a light shield or opaque disk 105.

The fibers 102 have an input or light-collecting end 103 with a light-collecting portion 106 and an output or terminal end 108. A ferrule 110 holds the terminal ends 108 of the fibers 102 together. The light-collecting portion 106 of the fibers 102 are arraigned in a pattern 112 and positioned about the light source 104. The pattern shown is a square pattern, for example a 25mm (1 inch square). The fibers 102 are placed in parallel in the pattern 112 as shown. To help maintain this pattern, the light-collecting portions 106 may be attached to a reflective backing 114. A reflective end piece 128 is positioned at the light-collecting end 103 of the fibers 102 to reflect light toward the terminal ends 108.

The opaque disk 105 is designed to limit the amount of direct illumination from the light source 104 that reaches the light-collecting portions 106 in an attempt to assure that light reaching the detecting surface is back scattered or reflected light that has propagated through a sufficient amount of tissue to have some level of modulation from

the pulsing capillary and arterial blood just below the surface of the patient's skin. The opaque disk 105 is dimensioned to minimize direct illumination and can be dependent upon the intensity of the light source 104. With a light source 104 generating an optical signal at a predefined intensity, the opaque disk 105 can have a radius of between 1mm and 20mm, preferably between 3mm and 10mm and more preferably between 5mm and 7mm for the optimal detection of pulsing blood from arterial sources. The opaque disk 105 may be constructed of substantially any material capable of limiting the direct illumination, such as, metal, opaque plastic or other materials or combination of materials capable of limiting direct illumination.

The optical fibers 102 collect the light reflected by the tissue of the patient or subject being measured and/or monitored. The optical fibers 102 direct the collected light through them to the terminal end 108, which may be attached to a light or optical signal detector 116. The optical detector 116, such as one or more photo diodes or phototransistors, is mounted near the terminal end 108 the fiber optics 102, proximate the ferrule 110. A photo preamplifier 118 may be mounted on the sensor 100, adjacent to the photo diode 116. This close coupling of the photo diode 116 tends to reduce the induction of electrical noise generated by other electronics and electrical systems located in close proximity to the sensor. Also, it is reasonably easy to make sensor gain changes by changing the feedback resistor in the photo preamplifier and selecting amplifiers with high frequency gain bandwidth characteristics. The light source 104 and detector 116 may be coupled to a processor, microprocessor and/or computer where control signals are generated and the detected optical signals are processed and/or analyzed.

The each fiber 102 may be constructed of known fiber optic materials, for example a plastic material, that is .25mm (0.01 inches) in diameter. Commonly, the optical fibers are designed to transmit light in a circular fiber having a core material with a specific index of refraction and an outer cladding having a different refractive index. In the embodiment shown in Figs. 1A-1C, the reflected light is received through the outer cladding before it gets into the core material.

Fig. 2 shows a cross-sectional view of a low profile fiber optic sensor 200 according to another embodiment of the present invention. Sensor 200 is similar to the sensor 100 described above except that the optical fibers 202 have a portion of their outer cladding 220 removed, exposing the core material 222 in the light-collecting portions 206 along a surface 224 of the fiber 202. By removing a portion of the outer cladding 220, more reflected light is captured and transmitted through the optical fiber 202. The low profile fiber optic sensor 200 has improved performance over the sensor 100 by increasing the amount of captured light by as much as 10%.

Figs. 3A-3C show a low profile fiber optic sensor 300 according to another embodiment of the present invention. The sensor 300 includes a plurality of optical fibers 302 and one or more light-emitting devices or sources 304 placed near a center of an opaque disk 305. The plurality of fibers 302 have an input or light-collecting end 202? with a light-collecting portion 306 and an output or terminal end 308. A portion of the outer cladding 320 of the fiber 302 is removed in the light-collecting portion 306, exposing the core material 322 along a surface 324. The light-collecting portions 306 are arranged in a pattern 312 and positioned about the light source 304. The plurality of fibers 302 are placed in parallel in the pattern 312 as shown. To help maintain this pattern, the light-collecting portions 306 may be attached to a reflective backing 314. A plurality of small spheres 326 are attached to the fiber optics 302 along the surface 324, opposite the reflective backing 314. The spheres 326 have the effect of focusing the light longitudinally into the core 322 by bending the light toward the fiber axis, which results in directing a larger portion of the reflected illumination incident on the sensor toward the terminal end 308. The fiber is approximately .25mm in diameter and the spheres of a test sensor are approximately .5mm in diameter. Additionally, it has been observed that spheres having a diameter somewhat smaller than that of the fiber optic strands tend to provide a more efficient coupling. The spheres 326 may be formed of substantially any material capable of collecting and propagating light, including glass, optical quality silicone rubber, plastic, polycarbonate, water clear polycarbonate plastic and other similar materials or combination of materials. The spheres 326 are attached to the fibers 302 along the surface 324 using an optically clear adhesive. Figure 3D shows a similar embodiment using hemispheres 330 instead of the spheres 326 shown in Fig. 3C. A

reflective end piece 328 is positioned at the light-collecting end 303 of the fibers 302 to reflect light toward the terminal ends 308. A ferrule 310 holds the fiber terminal ends 308 together. The light collection portion 306 of the fibers 302 collect the light reflected by the tissue of the patient or subject being measured and/or monitored. The fibers 302 transports the collected light through them to the terminal end 308 where the light strikes a light or optical signal detector 316. The optical detector 316, such as one or more photo diodes or phototransistors, is mounted near the terminal end 308 the fibers 302, proximate the ferrule 310. The optical detector 316 may be attached to a photo preamp 318.

Figs. 4A-4C show a low profile fiber optic sensor 400 according to another embodiment of the present invention. The sensor 400 includes a plurality of optical fibers 402 and one or more light-emitting devices or sources 404 placed near a center of an opaque disk 405. The optical fibers 402 have an input or light-collecting end 403 with a light-collecting portion 406 and an output or terminal end 408. A portion of the outer cladding 420 is removed in the light-collecting portion 406, exposing the core material 422 along a surface 424. The light-collecting portions 406 are arraigned in a pattern 412 and positioned about the light source 404. The optical fibers 402 are placed in parallel in the pattern 412 as shown. To help maintain this pattern, the light-collecting portions 406 are attached to a reflective backing 414. A plurality of small hemispheres 430 are attached to the fiber optics 402 along the surface 424, opposite the reflective backing 414. The hemispheres 430 have the effect of redirecting and focusing the light longitudinally into the core 422, which results in directing a larger portion of the reflected illumination incident on the sensor toward the terminal end 408. In this embodiment, the hemispheres and fibers have the same diameter, the fibers 402 are approximately .5mm in diameter and the hemispheres 430 are approximately .5mm in diameter. The hemispheres 430 may be made from optical materials, such as glass or optical quality silicone rubber, and are attached to the fiber optics 402 along the surface 424 using an optical adhesive. Optionally, the hemispheres 430 lenses may be molded using an optical silicon rubber material and cemented to the surface 424 of the plastic optical fibers 402. By using soft flexible silicon rubber, the sensor will be even more compliant than realized by the low profile fiber optic sensor 300 disclosed above having glass or plastic spheres cemented

onto the fibers. An additional advantage of the molded hemispheres lens system is that it is easier to manufacture and assemble, thus reducing the overall cost of the low profile fiber optic sensor 400.

A ferrule 410 holds the terminal ends 408 together. A reflective end piece 428 is positioned at the light-collecting end 403 of the fibers 402 to reflect light toward the terminal ends 408. The light collection portion 406 of the fibers 402 collect the light reflected by the tissue of the patient or subject being measured and/or monitored. The fibers 402 transport the collected light through them to the terminal end 408, where the light strikes a light or optical signal detector 416. The optical detector 416, such as one or more photo diodes or phototransistors, is mounted near the terminal end 408 the fiber optics 402, proximate the ferrule 410. The optical detector 416 may be attached to a photo preamp 418.

Figs. 5A-5D show a low profile fiber optic sensor 500 according to another embodiment of the present invention. The sensor 500 includes a plurality of optical fibers 502 and one or more light-emitting devices or sources 504 placed near a center of an opaque disk 505. The optical fibers 502 have an input or light-collecting end 503 with a light-collecting portion 506 and an output or terminal end 508. A portion of the outer cladding 520 of the fiber 502 is removed in a light-collecting portion 506, exposing the core material 522 along a surface 524. The light-collecting portions 506 may be arranged in a pattern 512 and positioned about the light source 504. The optical fibers 502 are placed in parallel in the pattern 512 as shown.

An array 534 of microprisms 535 are attached to the fiber optics 502 along the surface 524, the array 534 being oriented perpendicular to the axis of the fiber optics 502. The microprisms 535 are formed between two layers of material, a first layer 536 and a second layer 538 (see Fig. 5D). By having the microprisms formed this way, the microprisms are not distorted by skin contact pressure or affected by the index of adjacent material. The purpose of the array 534 is to bend the reflected light from the skin in the direction of the fiber axis, so that more light rays will be within the critical angle entering the core 522. One way to accomplish this is to make each of the layers

from materials having a different index of refraction. The reflected light 540 is shown entering the first layer 536 from the skin, where it makes contact with the prism 535. As the light enters the second layer 538, the light is bent toward the axis of the fiber 502. As the light 540 enters the core 522, it is again bent toward the fiber axis. Once inside the core 522, the light 540 travels down the fiber 502 reflecting along the cladding 520. As shown in this example, there is favorable bending of light 540 at the prisms 535 and again at the core 522.

The optical fiber 502 may be approximately .25mm to .50mm in diameter and may be made from optical materials, such as glass or optical quality silicone rubber. The first layer 536 and the second layer 538 may be molded using an optical silicon rubber material and the array may be attached to the fibers 502 along the surface 524 using an optical adhesive. Other methods of manufacture may also be used, for example the layers may be extruded. By using soft flexible silicon rubber or optical grade polyvinyl where the relative index of refraction between layers can be controlled the sensor will be compliant. An additional advantage of molding is that it is easier to manufacture and assemble, thus reducing the overall cost of the low profile fiber optic sensor 500.

A ferrule 510 holds the terminal ends 508 together. A reflective end piece 528 is positioned at the light-collecting end 503 of the fibers 502 to reflect light toward the terminal ends 508. The optical fibers 502 direct the collected light 540 through them to the terminal end 508, where the light strikes a light or optical signal detector 516. The optical detector 516, such as one or more photo diodes or phototransistors, is mounted near the terminal end 508 of the fibers 502, proximate the ferrule 510. The optical detector 516 may be attached to a photo preamp 518.

Figs. 6A-6E show a low profile fiber optic sensor 600 according to another embodiment of the present invention. One advantage of this embodiment is that there is no electronics in the sensor. The sensor 600 includes a fiber optic fan 603, a fiber optic light-emitting (LED) pipe 604, a mask ring or opaque disk 606, a prism lens 608, a connector 610, and a cover 612. In one embodiment, the fiber optic fan 603 is composed of a plurality of optical fibers 602 with an input or light-collecting portion 616 and an

output or terminal end 618. A portion of the outer cladding 620 of the fibers 602 is removed in a light-collecting portion 616, exposing the core material 622 along a surface 624. The light-collecting portions 616 are arranged in a pattern and positioned about the light-emitting (LED) pipe 604. The cover 612 is used to cover the fiber optic fan 603 and attach the low profile fiber optic sensor 600 to the skin.

The prism lens 608 includes an array 634 of microprisms 635 that are attached to the fibers 602 along a surface 624, the array 634 being oriented perpendicular to the axis of the fibers 602. The microprisms 635 are formed between two layers of material, a first layer 636 and a second layer 638. By having the microprisms formed this way, the microprisms are not distorted by skin contact pressure or affected by the index of adjacent material. The purpose of the prism lens 608 is to bend the light from the skin in the direction of the fiber axis, so that more light rays will be within the critical angle entering the core 622. One way to accomplish this is to make each of the layers from materials having a different index of refraction. The reflected light 640 is shown entering the first layer 636 from the skin, where it makes contact with the prism 635. As the light 640 enters the second layer 638, the light is bent toward the axis of the fiber 602. As the light enters the core 622, it is again bent toward the fiber axis. Once inside the core 622, the light 640 travels down the fiber, reflecting along the cladding 620. As shown in this example, there is favorable bending of light 640 at the prisms 635 and again at the core 622.

The fibers 602 may be approximately .25mm to .50mm in diameter and may be made from optical materials, such as glass or optical quality silicone rubber. The array 634 may be molded using an optical silicon rubber material. Optionally, the layers may be extruded. The first layer 636 and the second layer 638 may have the same or different indexes of refraction, depending on the particular prism design and the amount of bending that the light requires. The array 634 may be attached to the fiber optics 602 along the surface 624 using an optical adhesive. By using soft flexible silicon rubber, the overall design of the sensor will be compliant. An additional advantage of molding is that it is easier to manufacture and assemble, thus reducing the overall cost of the low profile fiber optic sensor.

A connector or ferrule 610 holds the terminal ends 618 together along with the input end of the LED pipe 604. The connector 610 is connected to one or more instruments 650 that is capable of emitting light at generate pulsed illumination at a first spectra of about 660 nm (red spectra) and at a second spectra of about 940 nm (near infrared spectra) and detecting the collected light with a detector.

In use, the instrument 650 emits a light at the desired spectra into the input end of the LED pipe 604. The light travels through LED pipe 604 to the output end, which is positioned near the center of the opaque disk 606, and the light enters the skin. The reflected light 640 returns from the skin and is picked up by the sensor 600 in the light collection area 616, where it enters the first layer 636 of the array 608. The light goes through the prism 635 and the second layer 638, where it is bent toward the axis of the fiber 602. The light enters the core 622 and reflects off the cladding 620 through the fiber 602 to the terminal end, where it is pick up by the detector in the instrument 650.

Optionally, the fiber optic fan 603 may use a "plate light pipe" instead of discrete optical fibers. The advantage of this approach is that more flexible materials may be utilized for greater conformability than discrete plastic optical fibers. This embodiment employs three layers in the collection area, bottom cladding, core and top cladding layers. The core and top cladding layers are simple plates, while the bottom cladding is an array of strips recessed into the second layer of the microprism array. The array of strips serve the same function as the partially remove cladding in the previous embodiment, it allows light in where the bottom cladding is missing and reflects the light along the core layer where it is present. The array of strips is preferentially oriented parallel to the direction of the terminal end and perpendicular to the microprisms. The array of strips may also function parallel to the microprisms. One of the differences between this "full fiber" embodiment and the previous embodiment with discrete fibers is that light can escape the "plate light pipe" at any stripe of missing cladding, while with discrete fibers the light has only one possible exit.

Figs. 7A-7B show a low profile fiber optic sensor 700 according to another embodiment of the present invention. The sensor 700 includes a plurality of optical

fibers 702 and one or more light-emitting devices or sources 704 placed near a center of an opaque disk 705. The light-emitting device 704 is a bi-color light-emitting diode (LED) that is activated to generate pulsed illumination at two predefined spectra. For example, the LED 704 can be configured to generate pulsed illumination at a first spectra of about 760 nm (red spectra) and at a second spectra of about 940 nm (near infrared spectra). However, illumination sources of virtually any spectral output can be used to make noninvasive optical measurements on patients or subjects.

The fibers 702 have an input or light-collecting end 706 and an output or terminal end 708. The input end 706 of the plurality of fibers 702 terminate in a circular pattern 712 surrounding the opaque disk 705. A sphere 732 is attached at the input end 706 of each fiber 702, to increase the effective pickup aperture of each fiber. This embodiment reduces the number of fibers required to compete a pattern around the bi-colored LED 704 and disk 705. A ferrule 710 holds the terminal ends 708 of the fibers 702 together. The fibers 702 collect the light reflected by the tissue of the patient or subject being measured and/or monitored. The fibers 702 transport the collected light through them to the terminal end 708, where the light strikes a light or optical signal detector 716. The optical detector 716, such as one or more photo diodes or phototransistors, is mounted near the terminal end 708 the fiber optics 702, proximate the ferrule 710. The optical detector 716 may be attached to a photo preamp 718.

The each fiber 702 may be constructed of known fiber optic materials, for example a plastic material, that is .25mm in diameter. Commonly, the fibers are designed to transmit light in a circular fiber having a core material with a specific index of refraction and an outer cladding having a different refractive index. In the embodiment shown in Figs. 7A-7B, the reflected light is received through spheres 732 at the input end 706, travels in the core material and exits the terminal end 708 striking the optical detector 716.

Typically, the low profile fiber optic sensor's described herein are placed on the surface of the skin of the subject. Pulsed illumination is projected into the surface of the skin and scattered through the tissue about the light source. The emitted light is

propagated through the tissue and modulated by pulsing variations in subcutaneous blood, blood vessels, capillaries and other anatomy of the subject being measured and/or monitored. The reflected light is collected by the light-collecting portion or input end of the optical fiber and propagated through the fiber to the terminal end, where it is detected by the optical detector. The detector generates a signal proportional to the amount of detected light. The signal may be amplified by an amplifier and forwarded to external processor and display devices.

While the invention herein disclosed has been described by means of specific embodiments and applications thereof, numerous modifications and variations could be made thereto by those skilled in the art without departing from the scope of the invention.

I CLAIM:

CLAIMS

1. A low profile fiber optic sensor, comprising:
 - a fiber optic fan having a collecting end with a light-collecting portion, a terminal end, a core material extending from the collecting end to the terminal end and an outer cladding;
 - the light-collecting portion formed in a pattern having a shape with a first side and a second side;
 - a light source positioned proximate the first side of the pattern; and
 - an opaque light shield positioned about the light source.
2. The sensor of claim 1, wherein the fiber optic fan consists of a plurality of optical fibers.
3. The sensor of claim 3, wherein the optical fibers are positioned parallel to each other in the collecting portion forming the pattern, the first side of the pattern being substantially perpendicular to an axis of the plurality of optical fibers.
4. The sensor of claim 3, wherein the outer cladding of the optical fibers is partially removed in the pattern exposing the core material on the first side of the pattern.
5. The sensor of claim 4, further comprising an optical lens coupled to the core material on the first side of the pattern.
6. The sensor of claim 5, wherein the lens consists of a plurality of optical spheres.

7. The sensor of claim 6, wherein the plurality of optical spheres are formed in a sheet of optical spheres.

8. The sensor of claim 5, wherein the lens consists of a plurality of optical hemispheres spheres.

9. The sensor of claim 8, wherein the plurality of optical hemispheres spheres are formed in a sheet of optical spheres.

10. The sensor of claim 5, wherein the lens consists of an array of microprisms.

11. The sensor of claim 12, wherein the array of microprisms are formed between a first material and a second material.

12. The sensor of claim 13, wherein the first material has a first index of refraction and the second material has a second index of refraction.

13. The sensor of claim 3, further comprising a reflective backplane proximate the second side of the pattern.

14. The sensor of claim 1, further comprising a reflective end piece proximate the collecting end.

15. The sensor of claim 1, wherein the fiber optic fan consists of a plate light pipe.

16. The sensor of claim 15, wherein the first side of the pattern is substantially parallel to an axis of the plate light pipe.

17. The sensor of claim 16, wherein the outer cladding of the plate light pipe is partially removed on the first side of the pattern exposing the core material.

18. The sensor of claim 17, further comprising an optical lens coupled to the core material on the first side of the pattern.

19. The sensor of claim 18, wherein the lens consists of an array of microprisms.

20. The sensor of claim 19, wherein the array of microprisms are formed between a first material and a second material.

21. The sensor of claim 20, wherein the first material has a first index of refraction and the second material has a second index of refraction.

22. The sensor of claim 18, wherein the lens consists of a plurality of optical spheres.

23. The sensor of claim 18, wherein the lens consists of a plurality of optical hemispheres spheres.

24. The sensor of claim 2, wherein the light shield includes an exterior perimeter and the collecting end of the optical fibers form the pattern about the exterior perimeter of the light shield.

25. The sensor of claim 24, wherein each optical fiber collecting end includes a light-collecting sphere attached thereon.

26. The sensor of claim 25, wherein the exterior perimeter is circular and the pattern shape is an annular detecting ring about the exterior perimeter.

27. The sensor of claim 1, further comprising a light detector coupled to the terminal end of the fiber optic fan.

28. The apparatus of claim 27, wherein the light source is a light-emitting diode (LED) capable of generating pulsed illumination.

29. The apparatus of claim 28, wherein the pulsed illumination is a first spectra at 660 nm and a second spectra at 940 nm.

30. The apparatus of claim 28, further comprising a controller.

31. The apparatus of claim 30, wherein the controller is coupled to the light source and light detector.

32. The sensor of claim 31, wherein the light detector is a photo diode.

33. The apparatus of claim 1, wherein the light source is a light pipe capable of transmitting light from a first end to a second end, the first end being proximate the first side of the pattern and the second end capable of coupling with a light-emitting diode .

34. The apparatus of claim 33, further comprising a light-emitting diode (LED) coupled to the second end of the light pipe.

35. The sensor of claim 34, further comprising a light detector coupled to the terminal end of the fiber optic fan.

36. The apparatus of claim 35, further comprising a controller coupled to the light source and light detector.

37. The sensor of claim 1, further comprising an optical connector proximate the terminal end.

38. The sensor of claim 1, wherein the fiber optic fan is configured to direct light from the light-collecting portion to the terminal end.

39. The sensor of claim 1, further comprising a cover capable of attaching the light-collecting portion to a person's skin.

40. A low profile fiber optic sensor, comprising:

a fiber optic fan having a collecting end with a light-collecting portion, a terminal end, a core material extending from the collecting end to the terminal end and an outer cladding;

the light-collecting portion formed in a pattern having a shape with a first side and a second side; and

a light pipe having a first end positioned proximate the first side of the pattern and a second end proximate the terminal end.

41. The sensor of claim 40, wherein the light pipe is capable of receiving and transmitting pulsed illumination from the second end to the first end.

42. The sensor of claim 40, wherein the fiber optic fan is configured to direct light impinging from the light-collecting portion to terminal end.

43. The sensor of claim 40, wherein the first end of the light pipe is positioned near a center of the pattern.

44. The apparatus of claim 43, further comprising an opaque light shield positioned about first end of the light pipe on the first side of the pattern.

45. The sensor of claim 40, wherein the outer cladding is partially removed in the pattern area exposing the core material on the first side of the pattern.

46. The sensor of claim 45, further comprising an optical lens coupled to the core material on the first side of the pattern.

47. The sensor of claim 46, wherein the lens consists of an array of microprisms.

48. The sensor of claim 47, wherein the array of microprisms are formed between a first material and a second material.

49. The sensor of claim 48, wherein the first material has a first index of refraction and the second material has a second index of refraction.

50. The sensor of claim 46, wherein the lens consists of a plurality of optical spheres.

51. The sensor of claim 46, wherein the lens consists of a plurality of optical hemispheres spheres.

52. The sensor of claim 40, wherein the light pipe is substantially parallel to the fiber optic fan in the pattern area except the first end of the light pipe is substantially perpendicular to the pattern area.

53. The apparatus of claim 40, further comprising a light source proximate the second end of the light pipe

54. The apparatus of claim 53, wherein the light source is capable of generating pulsed illumination.

55. The apparatus of claim 54, wherein the pulsed illumination is a first spectra at 660 nm and a second spectra at 940 nm.

56. The sensor of claim 53 further comprising a light detector coupled to the terminal end.

57. The sensor of claim 54, wherein the light pipe is configured to direct pulsed light impinging the second end to the first end and the fiber optic fan is configured to direct light impinging on the light-collecting portion to the terminal end.

58. The apparatus of claim 56, further comprising a controller coupled to the light source and light detector.

59. The sensor of claim 40, further including a cover capable of attaching the light-collecting portion on the first side of the pattern to a person's skin.

60. A low profile fiber optic sensor, comprising:

a fiber optic fan having a collecting end with a light-collecting portion, a terminal end, a core material extending from the collecting end to the terminal end and an outer cladding;

the light-collecting portion formed in a pattern having a shape with a first side and a second side, the outer cladding partially removed in the light-collecting portion exposing the core material on the first side of the pattern;

an optical lens proximate the first side of the pattern coupled to the core material;

a light pipe having a first end positioned proximate the first side of the pattern and a second end proximate the terminal end;

an opaque light shield positioned about the first end of the light pipe on the first side of the pattern; and

a cover capable of attaching the lens on the first side of the pattern to a person's skin.

61. The sensor of claim 60, wherein the lens consists of an array of microprisms.

62. The sensor of claim 60, wherein the lens consists of a plurality of optical spheres.

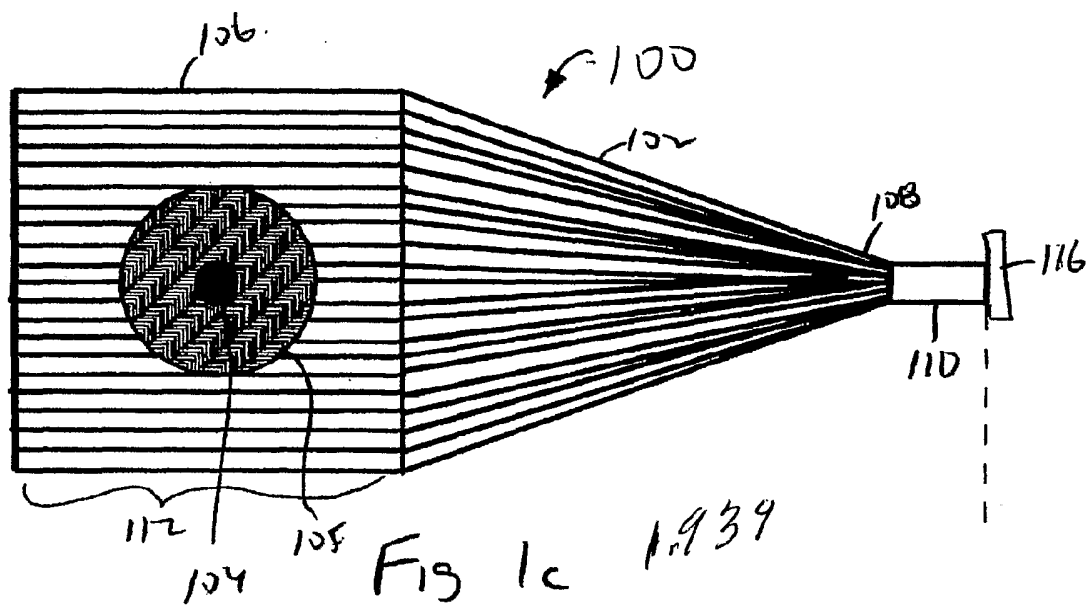
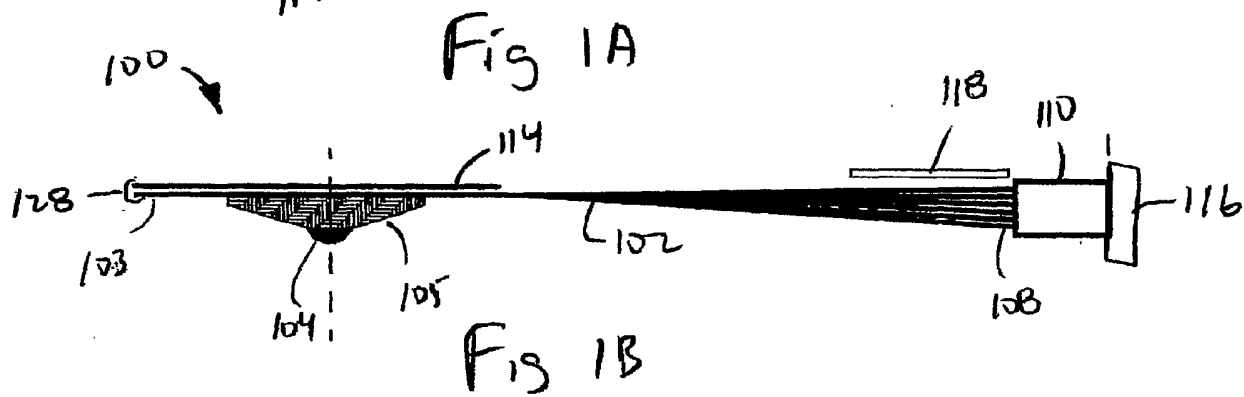
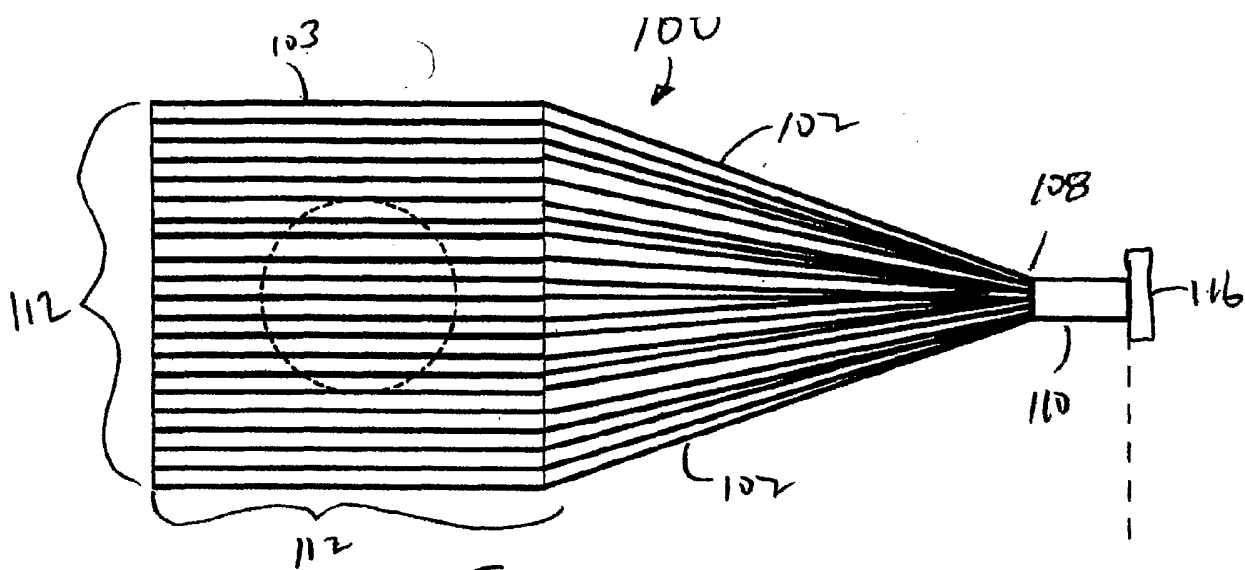
63. The sensor of claim 60, wherein the lens consists of a plurality of optical hemispheres spheres.

64. The sensor of claim 60, further comprising:

a light source proximate the second end of the light pipe capable of generating pulsed illumination;

a light detector proximate the terminal end; and

a controller coupled to the light source and light detector.



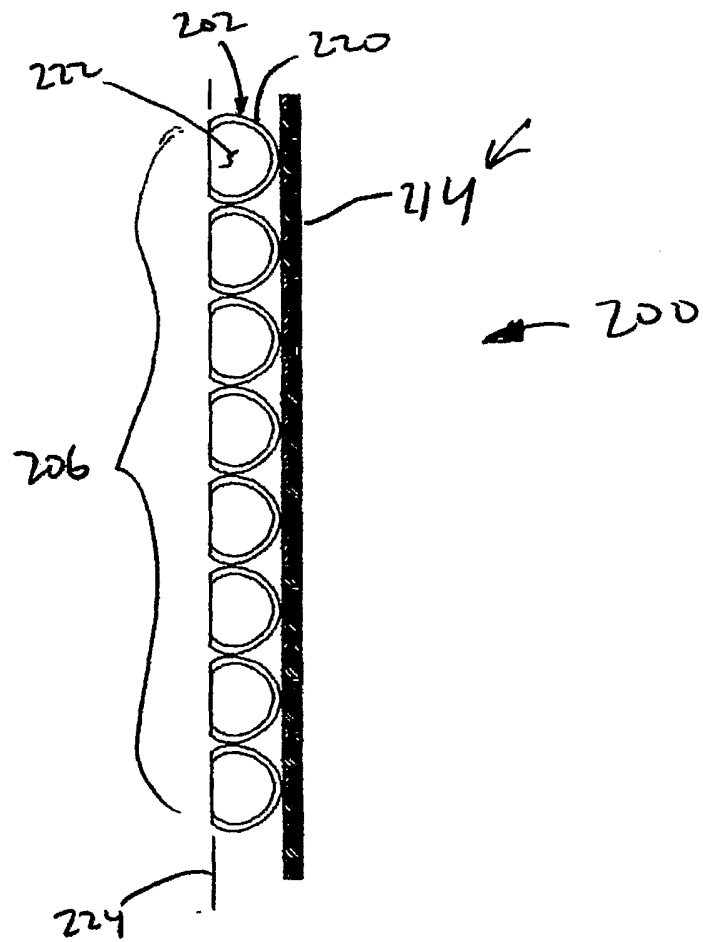


Fig. 2

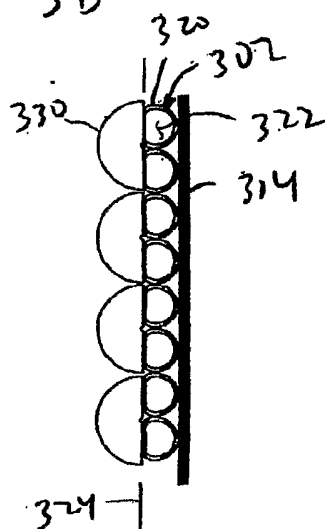
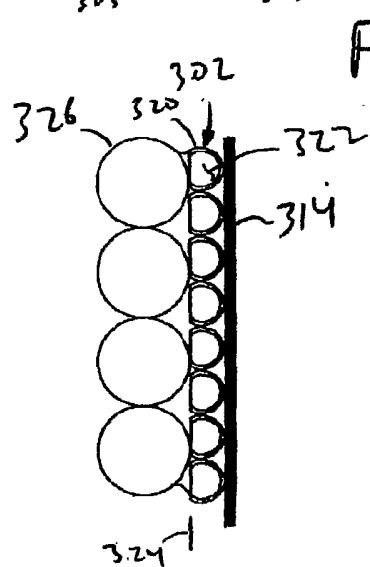
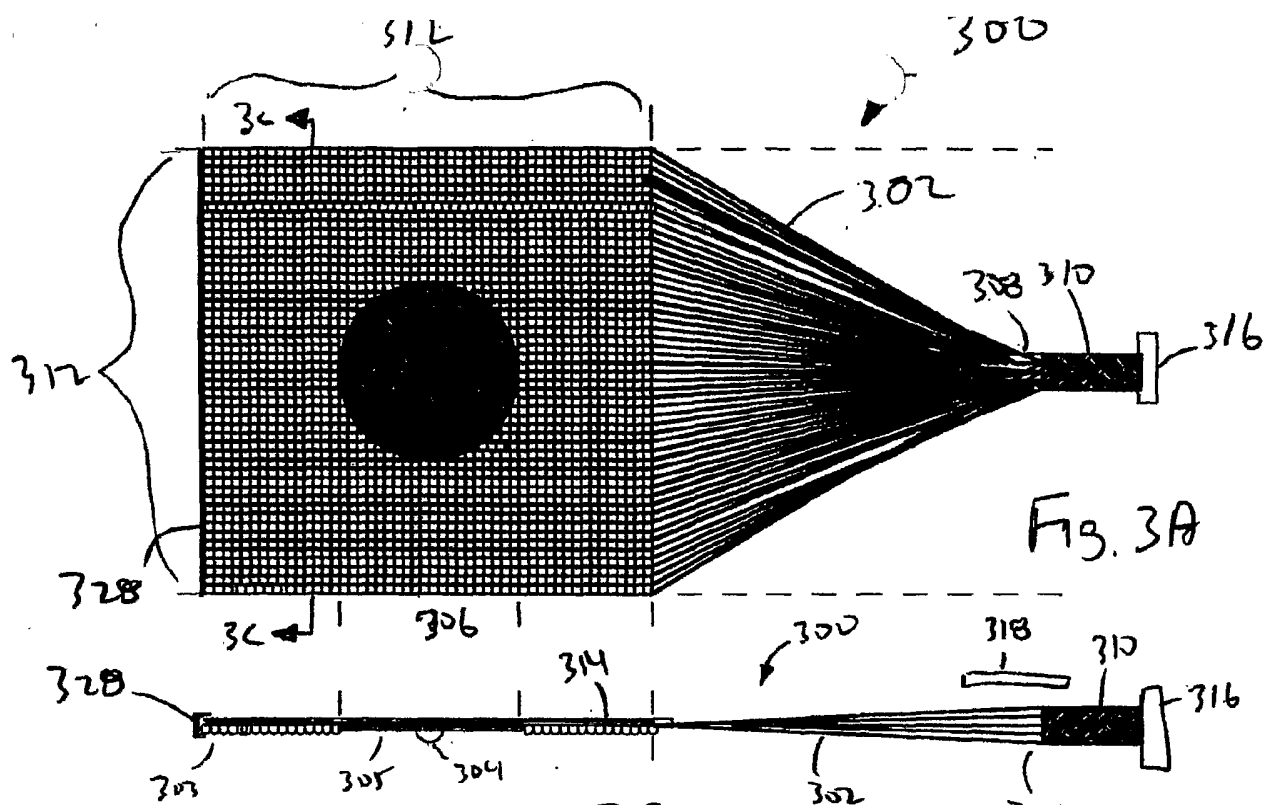
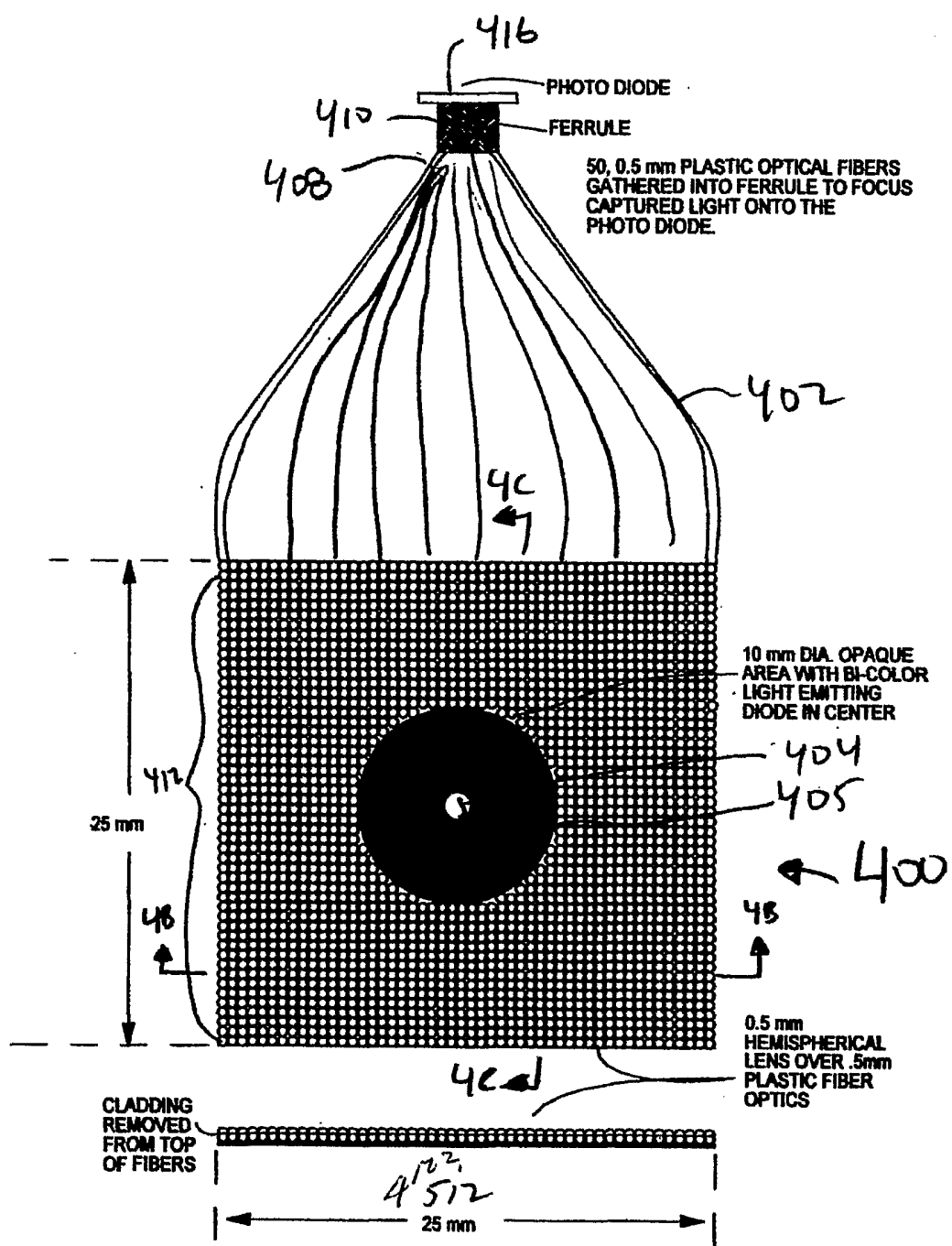


Fig. 3C

Fig 3D



F, S 4A

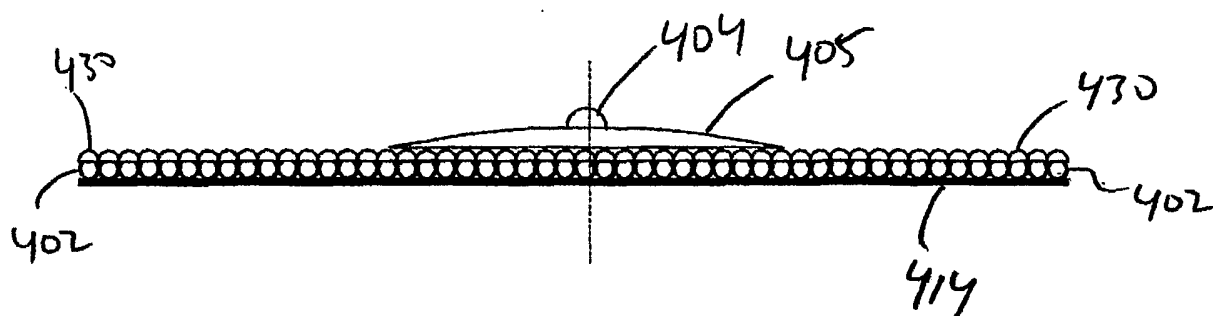


Fig 4B

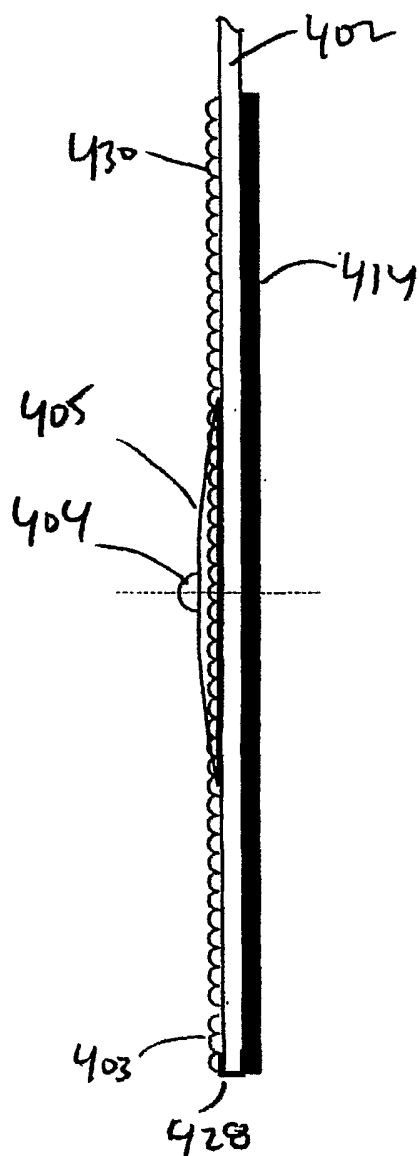
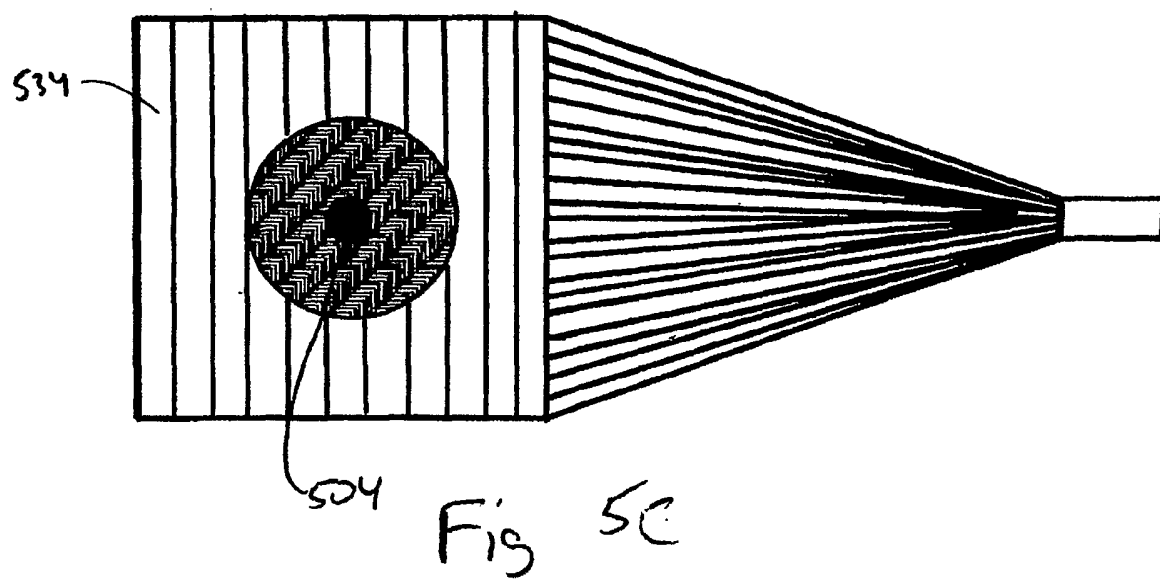
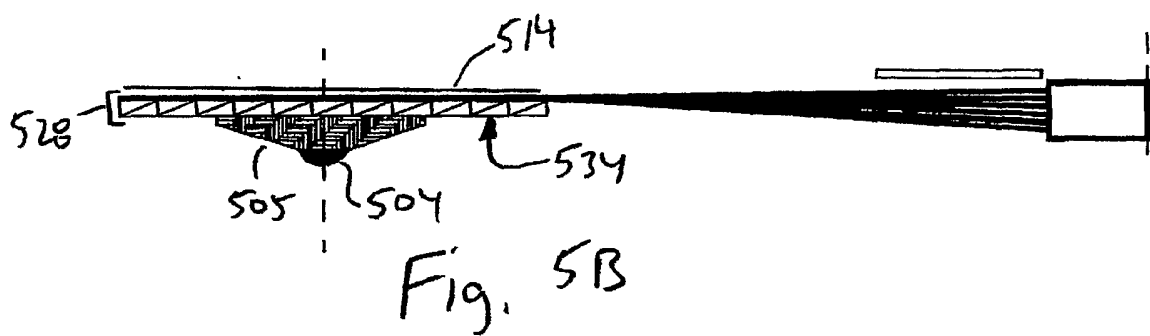
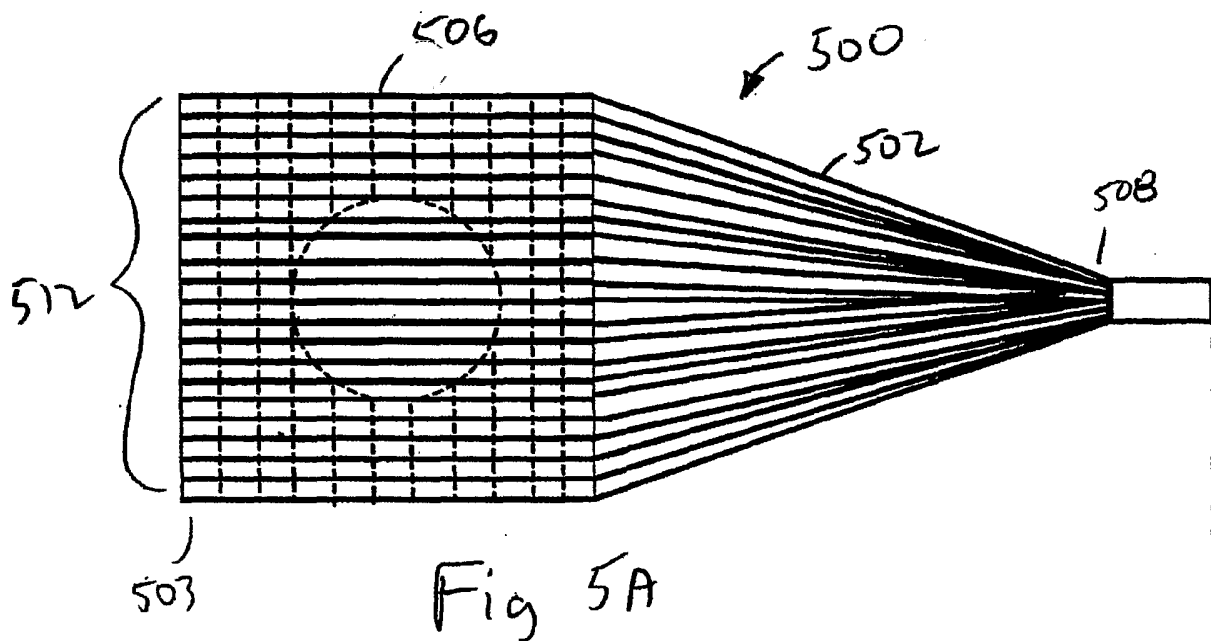


Fig 4C



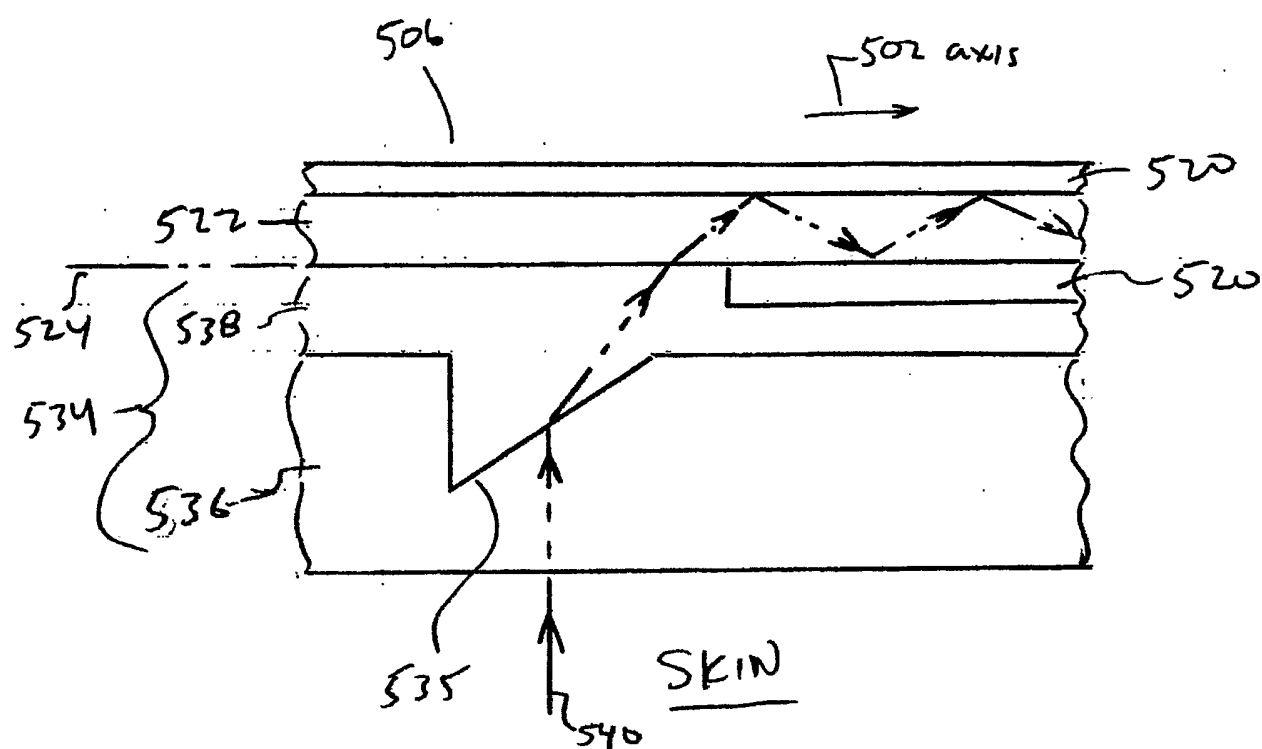


Fig 5D

ZONE	REV.	DESCRIPTION	DATE	APPROVED

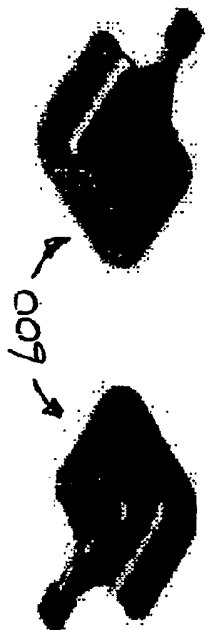


Fig. 6B

Fig. 6A

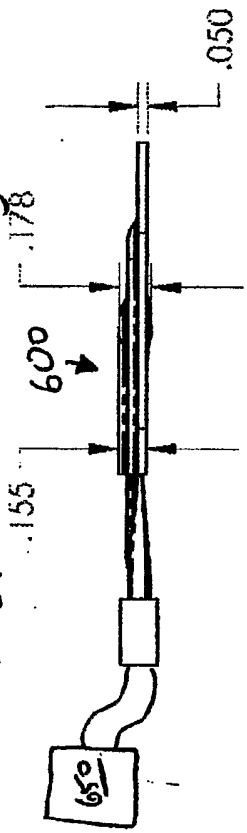


Fig. 6C

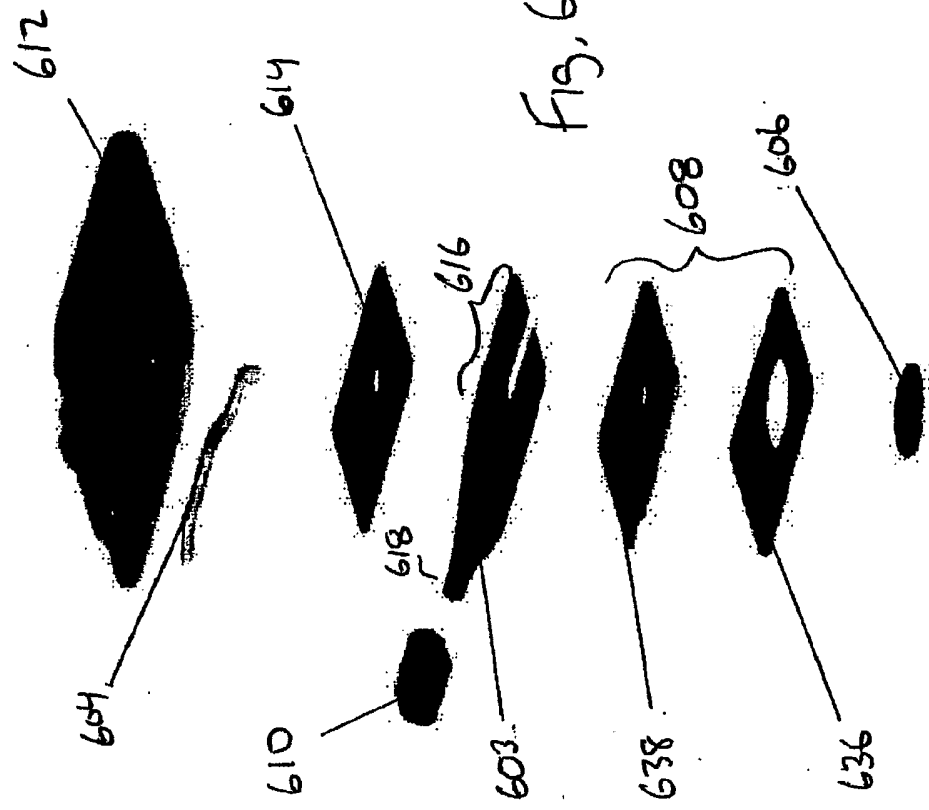


Fig. 6D

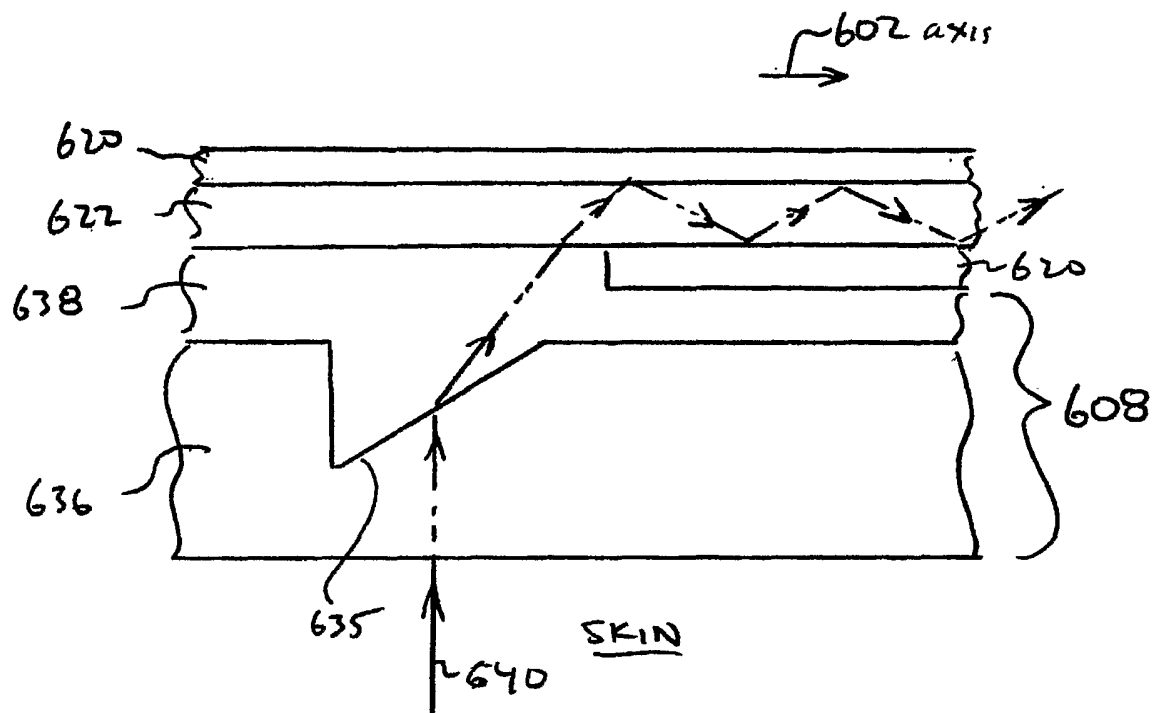


Fig 6E

