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(54) Optical probe for optical imaging system

(57) Methods and apparatus for monitoring oxygen saturation levels in tissue are disclosed. According to one aspect of the present invention, a sensor arrangement for use in an optical imaging system includes a first source structure, a second source structure, and a detector arrangement. The first source structure provides a first beam of light and the second source structure provides a second beam of light. The detector arrangement includes detector structures that have centerpoints, and receives the first and second beams of light after the first and second beams of light are reflected off of an external surface. The detector arrangement is arranged to define a first axis that passes through the centerpoint of each detector structure, and a distance from a centerpoint of the first source structure to the first axis is not equal to a distance from a centerpoint of the second source structure to the first axis.

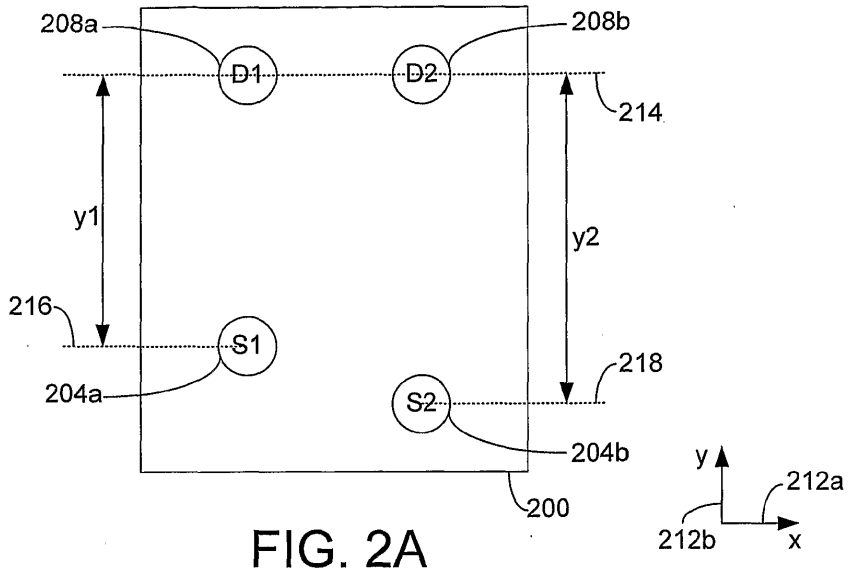

FIG. 2A

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Description

BACKGROUND OF THE INVENTION

1. Field of Invention

[0001] The present invention relates generally to optical imaging systems that monitor oxygen levels in tissue. More specifically, the present invention relates to optical probes that include sources and detectors that are not symmetrically arranged on sensor heads of the optical probes.

2. Description of the Related Art

[0002] Near-infrared spectroscopy has been used for non-invasive measurement of various physiological properties in animal and human subjects. The basic principle underlying the near-infrared spectroscopy is that physiological tissues include various highly-scattering chromophores to the near-infrared waves with relatively low absorption. Many substances in a medium may interact or interfere with the near-infrared light waves propagating therethrough. Human tissues, for example, include numerous chromophores such as oxygenated hemoglobin, deoxygenated hemoglobin, water, lipid, and cytochrome, where the hemoglobins are the dominant chromophores in the spectrum range of approximately 700 nm to approximately 900 nm. Accordingly, the near-infrared spectroscope has been applied to measure oxygen levels in the physiological medium such as tissue hemoglobin oxygen saturation and total hemoglobin concentrations.

[0003] Various techniques have been developed for the near-infrared spectroscopy, *e.g.,* time-resolved spectroscopy (TRS), phase modulation spectroscopy (PMS), and continuous wave spectroscopy (CWS). In a homogeneous and semi-infinite model, both TRS and PMS have been used to obtain spectra of an absorption coefficient and reduced scattering coefficient of the physiological medium by solving a photon diffusion equation, and to calculate concentrations of oxygenated and deoxygenated hemoglobins as well as tissue oxygen saturation. CWS has generally been designed to solve a modified Beer-Lambert equation and to measure changes in the concentrations of oxygenated and deoxygenated hemoglobins.

[0004] Despite their capability of providing the hemoglobin concentrations as well as the oxygen saturation, one major drawback of TRS and PMS is that the equipment is bulky and expensive. CWS may be manufactured at a lower cost but limited in its utility because it cannot compute the oxygen saturation from the changes in the concentrations of oxygenated and deoxygenated hemoglobins.

[0005] Optical Diffusion Imaging and Spectroscopy (ODIS) allows tissue to be characterized based on measurements of photon scattering and absorption. In tissue such as human tissue, near infrared light is highly scattered and minimally absorbed. Optical diffusion imaging is achieved by sending optical signals into tissue and measuring the corresponding diffuse reflectance or transmittance on the tissue surface.

[0006] Scattering is caused by the heterogeneous structure of a tissue and, therefore, is an indicator of the density of a cell and the nuclear size of the cell. Absorption is caused by interaction with chromophores. ODIS emits light into tissue through a sensor. The position of the light source which emits the light and a detector which detects the light allows a depth of measurement to be determined. A ratio of oxyhemoglobin and deoxyhemoglobin may be used to allow for substantially real-time measurement of oxygen, *e.g.,* oxygen saturation levels.

[0007] Within ODIS systems, sensors which come into contact with tissue surfaces generally have optical fibers arranged thereon in a substantially symmetric layout. That is, optical fibers that are coupled to light sources are arranged in a substantially symmetric orientation relative to optical fibers that are coupled to light detectors. While a symmetric orientation is effective in allowing for oxygen saturation levels to be measured, the manufacture of such sensor is often difficult, as the exact placement of the optical fibers within the sensor is crucial. Further, when the anatomy of tissue or underlying structure is not substantially symmetric, the use of a sensor with a symmetric orientation may not allow for accurate measurements to be readily made.

[0008] Therefore, what is needed is a sensor that is relatively easy to manufacture, and is arranged to be used on tissue which may not have a symmetric anatomy. That is, what is desired is a sensor with a layout of optical fibers for light sources and optical fibers for detectors that facilitates use with tissue having substantially any anatomy.

SUMMARY OF THE INVENTION

[0009] The present invention relates to a probe with a sensor that supports source fibers and detector fibers such that the source fibers have a substantially non-symmetric arrangement relative to the detector fibers. According to one aspect of the present invention, a sensor arrangement that is suitable for use in an optical imaging system and is arranged to contact a body such as tissue includes a first source structure, a second source structure, and a detector arrangement. The first source structure provides a first beam of light and the second source structure provides a second beam of light. The detector arrangement includes detector structures that each have a centerpoint, and receives the first beam of light and the second beam of light after the first beam of light and the second beam of light are reflected off of the body. The detector arrangement is arranged to define a first axis that passes through the centerpoint of each detector structure, and a distance from a centerpoint of the first source structure to the first axis is not equal to a distance

from a centerpoint of the second source structure to the first axis.

[0010] In one embodiment, a difference between the distance from the centerpoint of the first source structure to the first axis and the distance from the centerpoint of the second source structure is at least approximately 0.03 millimeters. In such an embodiment, the distance from the centerpoint of the first source structure to the first axis may be approximately 0.020 millimeters and the distance from the centerpoint of the second source structure to the first axis may be approximately 0.24 millimeters.

[0011] A probe with a sensor or a sensor head that has source structures in a non-symmetric orientation with respect to detector structures enables the sensor head to be utilized to monitor tissue with an underlying anatomy that is not substantially symmetric. The lack of symmetry also effectively loosens manufacturing tolerances associated with the manufacture of such sensor. Any attenuation associated with the offset orientation of optical fibers that are coupled to light sources is typically compensated for through the use of software code devices executing with respect to an optical imaging system. Hence, the amount of compensation applied may be relatively easily varied as needed to accommodate inaccuracies in the positioning of optical fibers with respect to the sensor.

[0012] According to another aspect of the present invention, a sensor arrangement that is suitable for use in an optical imaging system includes a first source structure that is arranged to provide a first beam of light and a second source structure that is arranged to provide a second beam of light. The sensor arrangement also includes a detector arrangement that has a first detector structure with a first centerpoint and a second detector structure with a second centerpoint. The detector arrangement is arranged to receive the first beam of light and the second beam of light after the first beam of light and the second beam of light are reflected off of a body. An orientation of the first source structure with respect to the detector arrangement is not symmetric relative to an orientation of the second source structure with respect to the detector arrangement.

[0013] According to yet another aspect of the present invention, a method for taking an oxygen saturation measurement of tissue using an optical system that utilizes a probe with a sensor head in which a first source structure and a second source structure are offset relative to detector structures involves positioning the sensor head in contact with the tissue and transmitting light into the tissue through the first source structure and the second source structure. The method also involves receiving reflected light from the tissue at the detector structures that includes attenuation characteristics, and processing the reflected light using a plurality of photodetectors. Processing the reflected light using the plurality of photodetectors includes compensating for the attenuation characteristics using an attenuation compensator.

[0014] In accordance with still another aspect of the present invention, a probe which may be used as a part of an optical system to monitor oxygen levels in tissue includes a coupling interface that allows the probe to be coupled to light sources and detectors. A sensor head of the probe is arranged to contact the tissue, and supports a first source structure, a second source structure, and a detector arrangement. The first source structure and the second source structure are coupled to the light sources via the coupling interface, while the detector arrangement is coupled to the detectors through the coupling interface. An orientation of the first source structure relative to the detector arrangement is not symmetric with respect to an orientation of the second source structure relative to the detector arrangement.

[0015] In one embodiment, the detector arrangement includes detector structures that each have a centerpoint. In such an embodiment, the detector arrangement receives the first beam of light and the second beam of light after the first beam of light and the second beam of light are reflected off of the tissue. The detector arrangement defines a first axis that passes through the centerpoint of each detector structure of the plurality of detector structures such that a distance from a centerpoint of the first source structure to the first axis is unequal to a distance from a centerpoint of the second source structure to the first axis.

[0016] These and other,advantages of the present invention will become apparent upon reading the following detailed descriptions and studying the various figures of the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The invention may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. 1A is a block diagram representation of an optical imaging system with a sensor head which includes sources in an offset arrangement relative to detectors in accordance with an embodiment of the present invention.

FIG. 1B is a block diagram representation of an optical imaging system with a sensor head which includes sources in an offset arrangement relative to detectors, *i.e.,* optical imaging system 100 of FIG. 1A, in accordance with an embodiment of the present invention.

FIG. 2A is a diagrammatic representation of a sensor head with a pair of light sources that are in an offset arrangement relative to a pair of detectors in accordance with an embodiment of the present invention.

FIG. 2B is a diagrammatic representation of a sensor head with a pair of light sources that are in an offset arrangement relative to a set of four detectors in accordance with a first embodiment of the present invention.

FIG. 2C is a diagrammatic representation of a sensor head with a pair of light sources that are in an offset arrangement relative to a set of four detectors in accordance with a second embodiment of the present invention.

FIG. 3 is a block diagram representation of light sources and detectors that are associated with a sensor head in accordance with an embodiment of the present invention.

FIG. 4 is a process flow diagram which illustrates one method of utilizing a sensor head with light sources that are in an offset arrangement relative to detectors in accordance with an embodiment of the present invention.

FIG. 5 is a diagrammatic representation of an optical imaging system that includes a console and a decoupleable probe with a sensor head with light sources that are in an offset arrangement relative to detectors in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

[0018] A sensor head which is such that optical fibers that are coupled to light sources are arranged in an offset orientation relative to optical fibers that are coupled to detectors allows the sensor head to be utilized in areas in which tissue being monitored is not substantially symmetric. Any attenuation associated with the offset orientation of optical fibers that are coupled to light sources is typically compensated for through software. Such a sensor head is relatively easy to manufacture in that the placement of optical fibers that are coupled to light sources is less rigid, *i.e.,* any slight variation in the placement of the optical fibers may be corrected for using the software that compensates for attenuation. In addition, the use of software to compensate for attenuation associated with the placement of optical fibers on a sensor head essentially enables the sensor head to be used with both symmetric and asymmetric tissue anatomies.

[0019] As will be understood by those skilled in the art, a volume of tissue substantially immediately beneath a sensor head may either be homogeneous or inhomogenous depending upon the actual anatomical structures contained within this volume. By way of example, when a sensor head is positioned on skin overlying a thick region of adipose tissue, the distribution of signet cells and capillaries containing oxygenated hemoglobin is generally relatively uniform, *i. e.,* symmetric and homogenous. However, a sensor head may be positioned over a tissue volume in which underlying structure include arteries, veins, bone, tendon, cartilage, fascia, muscle, or pigmented lesions. Such tissue may have asymmetric anatomies that cause light to be reflected or absorbed asymmetrically due, for example, to regions that are either unusually reflective or absorptive. Software that compensates for attenuation may eliminate readings associated with light that reflects off of structures such as bone. Optical fibers that are coupled to sources and are positioned in a sensor head in an offset orientation relative to optical fibers coupled to detectors may facilitate the transmission and reading of light that avoids structures such as bone. Hence, the use of offset source optical fiber orientations facilitate the creation of specialized sensor heads that may be used to measure oxygen saturation in many different parts of a body.

[0020] FIG. 1A is a block diagram representation of an optical imaging system with a sensor head that includes source arrangements arranged in an offset orientation relative to detector arrangements in accordance with an embodiment of the present invention. An optical imaging system 100 includes a unit 104 and a probe 108 that are coupled via a connection interface 112. Connection interface 112 is generally a light-tight interconnection with a laser safety interlock that is arranged to substantially prevent laser light from being emitted through connection interface 112 when probe 108 is not coupled to unit 104. Connection interface 112 typically includes a panel connector (not shown) attached to unit 104 and a cable connector (not shown) attached to probe 108.

[0021] Unit 104 includes a first light source 116 and a second light source 120. First light source 116 and second light source 120, in the described embodiment, are each dual wavelength light sources. In other words, first light source 116 provides two wavelengths of light and second light source 120 provides two wavelengths of light. First light source 116 and second light source 120 may each include a laser diode that provides a light beam or pulse at a lower frequency and a laser diode that provides a light beam or pulse at a higher frequency. By way of example, first light source 116 and second light source 120 may each include a laser diode that produces visible red light of an approximately 690 nanometer (nm) wavelength and a laser diode that produces near infra red light of an approximately 830 nm wavelength. It should be appreciated, however, that the wavelengths of light produced by laser diodes associated with first light source 116 and second light source 120 may vary widely.

[0022] Light emitted by first light source 116 and light emitted by second light source 120 is provided to a beam combiner 124 via optical fibers (not shown). Each laser diode associated with first light source 116 and each laser diode associated with second light source 120 is provided on a separate optical fiber (not shown). Beam combiner 124 effectively merges the light from the laser diodes of first light source 116 and merges the light from the laser diodes of second light source 120. The merged light is then provided via output fibers (not shown) to connection interface 112. The output fibers are arranged to allow the merged or combined light to be homogenized to ensure that the light is substantially uniformly distributed across the output fibers when the light enters connection interface 112.

[0023] Through connection interface 112, light is provided to a sensor head 128 of probe 108. Within sensor head 128, optical fibers (not shown) provide the merged

light associated with first light source 116 and the merged light associated with second light source 120 to a surface of sensor head 128 that is arranged to come into contact with tissue 132. The optical fibers (not shown) are positioned such that they have an offset orientation with respect to optical fibers (not shown) that are associated with photodetectors 136 within unit 104. The orientation of source optical fibers and detector optical fibers will be described below with respect to FIGS. 2A-2C.

[0024] When sensor head 128 causes light to be transmitted into tissue 132, the reflected light is collected by optical detector fibers (not shown) that are coupled to photodetectors 136. In general, at least two photodetectors 136 are included within unit 104 and are configured to be sensitive to the light which is transmitted by first light source 116 and second light source 120. An attenuation compensator 140 within unit 104 is generally arranged to compensate for any attenuation in the reflected light that results from the offset orientation of source optical fibers (not shown) relative to detector optical fibers (not shown). In one embodiment, attenuation compensator 140 effectively provides compensation using a mathematical algorithm that constructs ratios in which attenuation coefficients may be found in both a numerator and a denominator and hence, may be cancelled out. Such ratios may use light intensities as detected by photodetectors 136 in such a way that attenuation factors have little effect on the evaluation of optical properties of tissue 132 beneath sensor head 128 It should be appreciated that attenuation compensator 140 may generally be substantially incorporated into software or firmware that executes an algorithm that determines oxygen saturation levels.

[0025] FIG. 1B is a block diagram representation of optical imaging system 100 of FIG. 1A which shows the path of light emitted by light sources, i. e., first light source 116 and second light source 120 of FIG. 1A, in accordance with an embodiment of the present invention. When first light source 116 emits light at two wavelengths, light of the first wavelength 152a and light of the second wavelength 152b are provided to beam combiner 124 which effectively merges the light into a light stream 152c that is provided to sensor head 128, e.g., through optical source fibers. Similarly, when second light source 120 emits light at two wavelengths, light of the first wavelength 156a and light of the second wavelength 156b are merged into a light stream 156c by beam combiner 124 that is provided to sensor head 128. Light streams 152c, 156c are transmitted into tissue 132 reflect off of tissue 132, through sensor head 128 to photodetectors 136.

[0026] As previously mentioned, optical source fibers are arranged such that at a surface of a sensor head that is arranged to come into contact with tissue, the optical source fibers have an offset orientation relative to optical detector fibers. With reference to FIG. 2A, the orientation of source fibers with respect to detector fibers will be described in accordance with an embodiment of the present invention. A sensor head 200, which may be of substantially any shape or size, is a part of a probe that is a part of an overall system that measures oxygen saturation levels in tissue. Sensor head 200 is arranged to accommodate source arrangements 204a, 204b, and detector arrangements 208a, 208b. For ease of discussion, although source arrangements 204a, 204b are generally fiberoptic cables or optical fibers coupled to light sources and detector arrangements 208a, 208b are generally fiberoptic cables or optical fibers coupled to photodetectors, source arrangements 204a, 204b are referred to herein as sources and detector arrangements 208a, 208b are referred to herein as detectors.

[0027] Sources 204a, 204b are arranged such that they are in an offset arrangement relative to detectors 208a, 208b. That is, source 204a and source 204b are not equidistant to detectors 208a, 208b relative to at least one axis. Detectors 208a, 208b are arranged such that a centerline 214 of detectors 208a, 208b is approximately parallel to an x-axis 212a. Typically, centerline 214 passes through a centerpoint of each detector 208a, 208b. Sources 204a, 204b are arranged such that a centerline 216 of source 204a is parallel to a centerline 218 of source 204b, but is not coincident with centerline 218. Centerline 216 passes through a centerpoint of source 204a and is parallel to x-axis 212a, while centerline 216 passes through a centerpoint of source 204b and is parallel to x-axis 212b.

[0028] A distance y1 between centerline 214 and centerline 216 along a y-axis 212b differs from a distance y2 between centerline 214 and centerline 218. Although distance y2 is shown as being greater than distance y1, it should be appreciated that distance y1 may instead be greater than y2. The difference between distance y2 and distance y1 is generally characteristic of the offset arrangement, or substantially unbalanced arrangement, of sources 204a, 204b relative to detectors 208a, 208b. In other words, there is effectively a lack of symmetry in the placement of sources 204a, 204b.

[0029] In general, more than two detectors may be used in conjunction with a pair of detectors to monitor oxygen saturation in tissue. By way of example, three or four detectors may be used to detect light that is provided by a pair of sources and is reflected off of a tissue surface. It should be appreciated that some of the light may be reflected from tissue at various depths beneath the tissue surface. That is, light may be reflected off the tissue surface and off of tissue that underlies the surface. The tissue that underlies the surface and allows light to be reflected may be as deep as approximately one centimeter below the surface of the tissue. FIG. 2B is a diagrammatic representation of a sensor head which is arranged to include a pair of sources or, more specifically, source arrangements and four detectors or, more specifically, detector arrangements, in accordance with an embodiment of the present invention. A sensor head 220 includes four detectors 228a-d which are arranged such that centerpoints of detectors 228a-d are substantially aligned along a centerline 234 that is substantially par-

allel to an x-axis 232a. Sensor head 220 also includes sources 224a, 224b which each include a centerpoint. A centerline 236 that is parallel to x-axis 232a passes through the centerpoint of source 224a, and a centerline 238 that is parallel to x-axis 232a passes through the centerpoint of source 224.

[0030] In the described embodiment, a distance y1 along a y-axis 232b between centerline 234 and centerline 236 is not equal to a distance y2 along y-axis 232b between centerline 234 and centerline 238. Distance y1 may be approximately 0.2 millimeters (mm), as for example approximately 0.197 mm, while distance y2 may be approximately 0.24 mm, as for example 0.236 mm. It should be appreciated that distance y1 and distance y2 may vary widely depending upon any number of factors. The factors include, but are not limited to, the overall size of sources 224a, 224b and detectors 228a-d, the overall size of sensor head 220, and the application for which sensor head 220 is intended. While distance y2 is shown as being greater than distance y1, distance y1 may instead be greater than distance y2. In general, the difference between distance y2 and distance y1 is at least approximately 0.3 mm. For example, distance y2 and distance y1 may differ by approximately 1.0 mm.

[0031] The positioning of sources 224a, 224b and detectors 228a-d may vary widely. By way of example, for an embodiment in which sources 224a, 224b and detectors 228a-d are each approximately one mm in diameter, centerpoints of sources 224a, 224b may be separated by a distance d2 that is approximately 0.22 mm relative to x-axis 232a and by a distance y4 that is approximately 0.04 mm. Detectors 228a-d may be arranged such that centerline 234 is offset from a top edge of sensor head 220 by a distance y3 that is approximately 0.06 mm, and such that adjacent detectors 228a-d are separated by a distance d1 that is between approximately 0.06 mm to approximately 0.07 mm. Sensor head 220 may have a width of approximately 0.34 mm along x-axis 232a and a height of approximately 0.49 mm along y-axis 232b when detectors 228a-d and sources 224a, 224b are spaced as described above. However, sensor head 220 generally has dimensions that may vary widely, e.g., dimensions which may vary depending upon the application for which sensor head 220 is intended.

[0032] While a lack of symmetry in the positioning of sensors relative to detectors has been described as being such that distances between sensors and detectors are not equal relative to a y-axis, a lack of symmetry may instead or additionally have a lack of symmetry relative to an x-axis. Referring next to FIG. 2C, a sensor head that includes a pair of sources which are in an offset arrangement relative to a set of four detectors with respect to an x-axis will be described. A sensor head 240 includes four detectors 248a-d, although the number of detectors 248a-d may vary. Detectors 248a-d are arranged such that a centerline 254 is substantially parallel to an x-axis 252a and passes through the centerpoint of each detector 248a-d. A first detector 248a and a last detector 248d, i.e., the detectors which are farthest apart relative to x-axis 252a, are used to define a central bisecting line 262 of detectors 248a-d. Central bisecting line 262 is parallel to a y-axis 252b, and is arranged such that a distance x3 from the centerpoint of detector 248a to central bisecting line 262 is substantially equal to a distance x4 from the centerpoint of detector 248d to central bisecting line 262. That is, central bisecting line 262 is arranged to pass through a central midpoint between the centerpoint of detector 248a and the centerpoint of detector 248d such that central bisecting line 262 is substantially perpendicular to centerline 254.

[0033] As shown, a centerpoint of a first source 244a and the centerpoint of first detector 248a are aligned along a centerline 257 that is substantially parallel to a y-axis 252b. Similarly, a centerpoint of a second source 244b and the centerpoint of last detector 248d may be aligned along a centerline 259 that is substantially parallel to y-axis 252b. It should be appreciated, however, that centerline 257 may not necessarily pass through the centerpoint of first detector 248a, and centerline 259 may not necessarily pass through the centerpoint of last detector 248d. That is, centerline 257 is effectively a line that is substantially parallel to y-axis 252b and passes through first source 244a, while centerline 259 is effectively a line that is substantially parallel to y-axis 252b and passes through second source 244b.

[0034] A distance x1 between centerline 257 and central bisecting line 262 is not equal to a distance x2 between centerline 259 and central bisecting line 262. In other words, first source 244a and second source 244b are not equidistant from central bisecting line 262. Hence, sources 244a, 244b are positioned in an offset or unbalanced orientation relative to x-axis 252a.

[0035] Sources are typically arranged to emit light of specific wavelengths. As discussed above, light of a lower wavelength emitted by a source may have a wavelength of approximately 690 nm, while light of a higher wavelength emitted by the source may have a wavelength of approximately 830 nm. FIG. 3 is a block diagram representation of light sources and detectors that are associated with a sensor head in accordance with an embodiment of the present invention. A first source may include a laser diode 302a that produces light at a wavelength of approximately 690 nm as well as a laser diode 302b that produces light at a wavelength of approximately 830 nm. Similarly, a second source may include a laser diode 306a that produces light at a wavelength of approximately 690 nm as well as a laser diode 306b that produces light at a wavelength of approximately 830 nm.

[0036] A beam combiner 310 is arranged to enable light emitted by laser diodes 302a, 302b to be merged onto an optical fiber 312 that is provided to a sensor head 322. Beam combiner 310 is also arranged to enable light emitted by laser diodes 306a, 306b to be merged onto an optical fiber 316 that is provided to sensor head 322. Light transmitted by fibers 312, 316 through a tissue or other surface is reflected, and the reflected light is effec-

tively captured on optical fibers 324 which provide the reflected light to photodetectors 318. Photodetectors 318 are arranged to be sensitive to light with wavelengths of approximately 690 nm and approximately 830 nm, and typically have a relatively high gain.

[0037] With reference to FIG. 4, one method of monitoring oxygen saturation in tissue using an oximeter with a sensor head in which sources are in an offset orientation relative to detectors will be described in accordance with an embodiment of the present invention. A process 400 of using an oximeter begins at step 404 in which a probe, *i.e.,* a probe that includes a sensor head in which sources are positioned in an offset orientation relative to detectors, is applied against tissue. Once the sensor head is positioned in contact with tissue, a first source S1 associated with the probe sends a lower wavelength pulse of light into the tissue in step 408. The first source S1 may include a laser diode that produces an approximately 690 nm wavelength of visible red light, as discussed above, although the lower wavelength of light produced by the first source S1 may vary. In general, first source S1 is a source arrangement that produces light at two wavelengths. Hence, first source S1 may include two substantially separate laser diodes that produce light at two wavelengths.

[0038] In step 412, a detector arrangement associated with the probe detects the approximately 690 nm light. As discussed above, when the approximately 690 nm light is transmitted into the tissue, the approximately 690 nm light is reflected into the detector arrangement such that the detectors, e.g., the photodetectors, included in the detector arrangement collect the reflected light. A second source S2 then sends a lower wavelength pulse of light in step 416 which, in the described embodiment, is an approximately 690 nm pulse of light. The detector arrangement detects and collects the approximately 690 nm reflected light in step 420.

[0039] Once the lower wavelength light is transmitted by both the first source S1 and the second source S2, the first source S1 sends a higher wavelength pulse of light into the tissue in step 424. The higher wavelength pulse of light may be an approximately 830 nm near infrared light produced by a laser diode included in first source S1. After the approximately 830 nm pulse of light is transmitted into the tissue and reflected, then process flow moves to step 428 in which detector arrangement detects the reflected light.

[0040] The second source S2 sends a higher wavelength pulse of light, e.g., light with an approximately 830 nm wavelength, in step 432 that is then reflected off of the tissue and reflected into the detector arrangement in step 436. Once the detector arrangement has received reflected light from both sensors at both the lower wavelength and the higher wavelength, the data acquisition arrangement of the oximeter processes information associated with the received reflected light in step 440. Processing the received reflected light may include executing software or firmware that accounts for or otherwise compensates for attenuation associated with the reflected light in order to determine an oxygen level associated with the tissue. Once the data acquisition arrangement process the information, the process of monitoring an oxygen saturation level of tissue is completed. It should be understood, however, the steps of FIG. 4 may be repeated to allow for the substantially continuous monitoring of an oxygen saturation level.

[0041] An oximeter which utilizes a probe with a sensor head of the present invention may include a portable console unit to which the probe may be coupled. As shown in FIG. 5, a console 500 may include a screen 504 that is arranged to display the oxygen saturation level of tissue that is being monitored. Screen 504, which may be a touchscreen, may also be arranged to indicate when a probe 520 is in use and to provide warnings to a user that indicate when a monitored oxygen saturation level is potentially problematic.

[0042] Console 500 includes a panel connector 508 to which a connector 528 of probe 520 may be connected to allow a sensor head 530 of probe 520 to be used to monitor oxygen saturation levels. Fiberoptic cables (not shown) which are used to allow light to pass between connector 528 and sensor head 530 of probe 520 are substantially encased in a cable jacket 534. Console 500 and probe 520 may be a part of the ODISsey Tissue Oximeter available commercially from ViOptix, Inc. of Fremont, California.

[0043] Although only a few embodiments of the present invention have been described, it should be understood that the present invention may be embodied in many other specific forms without departing from the spirit or the scope of the present invention. By way of example, the wavelengths emitted by light sources have been described as being approximately 690 nm and approximately 830 nm. However, substantially any wavelengths may be emitted by the light sources.

[0044] The probe on which a sensor head is mounted may have a variety of different configurations. For example, the probe may include a handpiece which facilitates spot measurements of tissue. Additionally, the configuration of a sensor head may also vary depending upon the particular application for which the sensor head is to be used.

[0045] A probe, e.g., a fiberoptic probe, on which a sensor head is mounted uses fiberoptic cable to carry an optical signal to an from tissue. The fiberoptic cable may be of any length, and may contain one dual wavelength source fibers for each source and one detector fiber for each detector. In one embodiment, the fiberoptic cable may be approximately three meters long, and the source and detector fibers may each have diameters of approximately one mm.

[0046] A centerpoint of a source optical fiber and a centerpoint of a detector optical fiber have generally been described as being centerpoints of fibers that are substantially circular in orientation. It should be appreciated that in some instances, when a fiber is not substantially

circular in orientation, the centerpoint may be an approximate centerpoint of the fiber.

[0047] The steps associated with the various methods of the present invention may be widely varied. Steps may be added, altered, removed, and reordered without departing from the spirit or the scope of the present invention. Therefore, the present examples are to be considered as illustrative and not restrictive, and the invention is not to be limited to the details given herein, but may be modified within the scope of the appended claims.

Claims

1. A tissue oximeter device comprising:

probe means for taking oximeter measurements comprising:

cable interface means for interfacing a cable means to a console means;
cable means for coupling the probe means to the cable interface means and allowing through the cable interface means coupling of the probe to a first radiation source means, a second radiation source means, and a first photodetector means, wherein the first radiation source means, second radiation source means, and first photodetector means are external to the probe means;
sensor head means comprising a first source structure means for emitting light and a first detector structure means for detecting light, the first source structure means being arranged to be coupled to the first and second radiation source means via the cable interface means, and the first detector structure means being arranged to be coupled to the first photodetector means via the cable interface means; and
console means for housing the first radiation source, second radiation source, and first photodetector means, wherein the console means is external to the probe, the first radiation source means is for generating first light, second radiation source means is for generating second light, first photodetector means is for detecting third light, and the console houses a beam combiner means for coupling the first and second radiation source means, the beam combiner means being external to the probe means.

2. The device of claim 1 wherein the probe means further comprises:

the sensor head means further comprises a second photodetector means and a third photodetector means, wherein the second photodetector means is between the first and third photodetector means,
the first source structure means, first photodetector means, and third photodetector means form vertices of a first right triangle, and a first hypotenuse of the first right triangle extends from the first source structure means to the third photodetector means without touching another source structure or photodetector means.

3. The device of claim 1 wherein the probe means comprises a first fiber optic cable means having a first end coupled to the first source structure means and a second end at the cable interface means for coupling to the beam combiner means.

4. The device of claim 3 wherein the probe means comprises a second fiber optic cable means having a first end coupled to the first detector structure means and a second end at the cable interface means for coupling to the first photodetector means.

5. The device of claim 1 wherein the sensor head means comprises a second source structure means and a second detector structure means, wherein the first and second detector structures means are arranged in a first row.

6. The device of claim 5 wherein the first source structure means and first detector structure means are arranged in a first column.

7. The device of claim 6 wherein the second source structure means and second detector structure means are arranged in a second column.

8. The device of claim 1 wherein the first radiation means source emits a 690-nanometer wavelength light and the second radiation source means emits an 830-nanometer wavelength light.

9. The device of claim 8 wherein an output of the beam combiner means is either the 690-nanometer wavelength light or the 830-nanometer wavelength light.

10. The device of claim 5 wherein the second detector structure means is coupled through the cable interface means to a second photodetector means, external to the probe means.

11. The device of claim 1 wherein the probe means comprises a cable means, coupled between the cable interface means and the sensor head means, the cable means comprising optical fibers means having a length of at least about three meters.

12. The device of claim 11 wherein the optical fibers

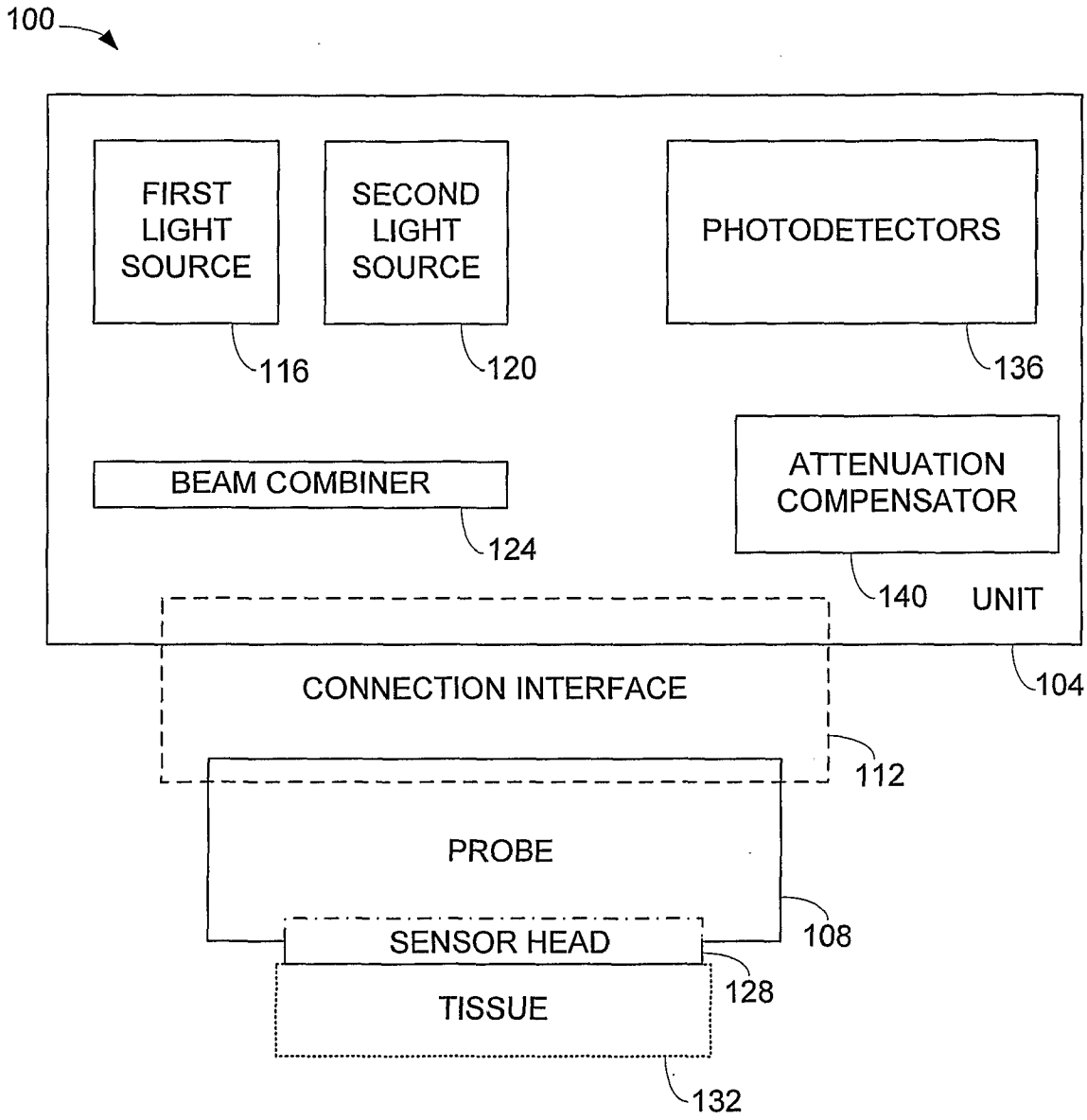
means have a diameter of at least one millimeter.

13. The device of claim 1 wherein a line extending through the first source structure means and the first detector structure means is parallel to an edge of the sensor head means.

14. The device of claim 1 wherein a lower wavelength light and a higher wavelength light are emitted, one wavelength of light at one time, from the first radiation source means and the second radiation source means through the beam combiner means to the first source structure means into a tissue, reflected light from the tissue is received at the first detector structure means and transmitted to the first photodetector means, and software executing in the console means makes a determination of an oxygen saturation of the tissue based on values of the lower wavelength light, higher wavelength light, and reflected light.

15. The device of claim 1 wherein the first radiation source means and second radiation source means comprise laser diodes.

16. The device of claim 1 wherein the first source structure means and the first detector structure means have the same cross-sectional area.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116
SECOND LIGHT SOURCE
120
PHOTODETECTORS
136
BEAM COMBINER
124
ATTENUATION COMPENSATOR
140
UNIT
104
CONNECTION INTERFACE
112
PROBE
108
SENSOR HEAD
128
TISSUE
132

FIG. 1A

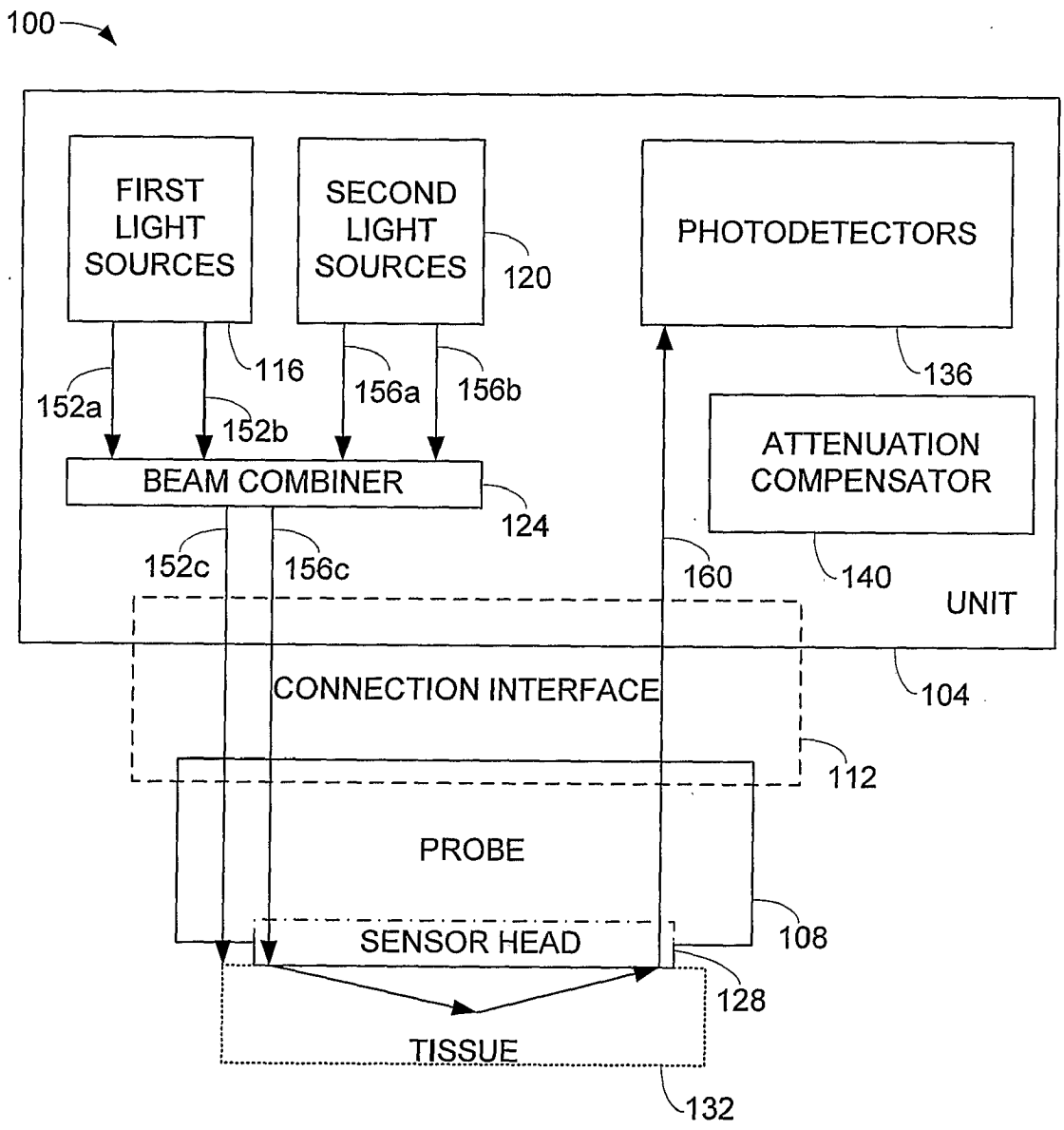
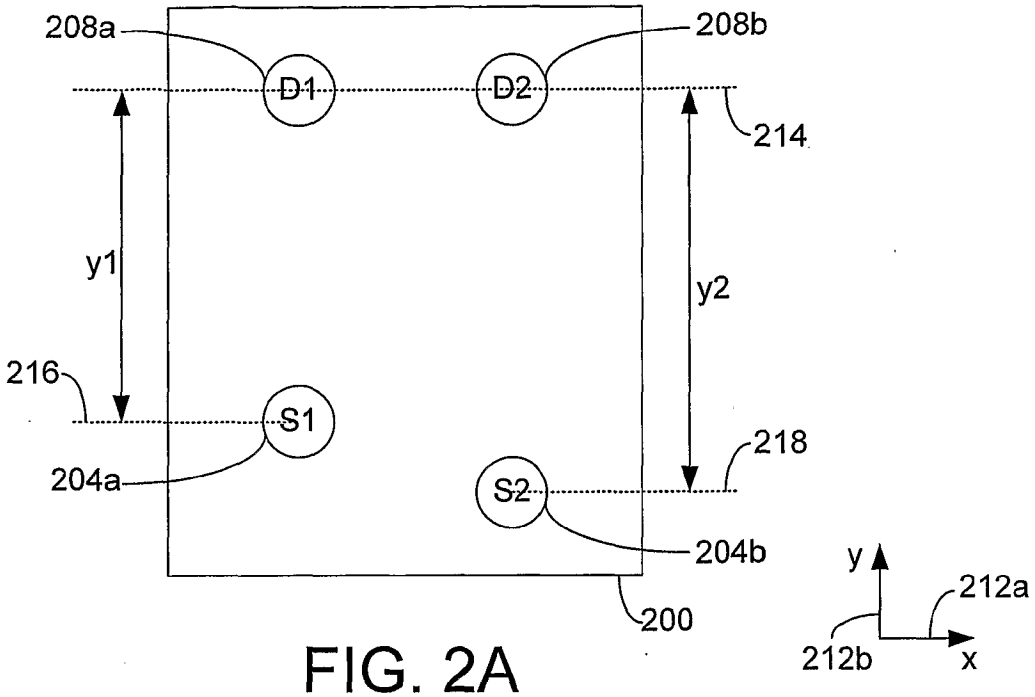

100
FIRST LIGHT SOURCES
SECOND LIGHT SOURCES
120
PHOTODETECTORS
136
116
152a
152b
156a
156b
ATTENUATION COMPENSATOR
BEAM COMBINER
124
152c
156c
160
140
UNIT
CONNECTION INTERFACE
104
112
PROBE
SENSOR HEAD
108
128
TISSUE
132

FIG. 1B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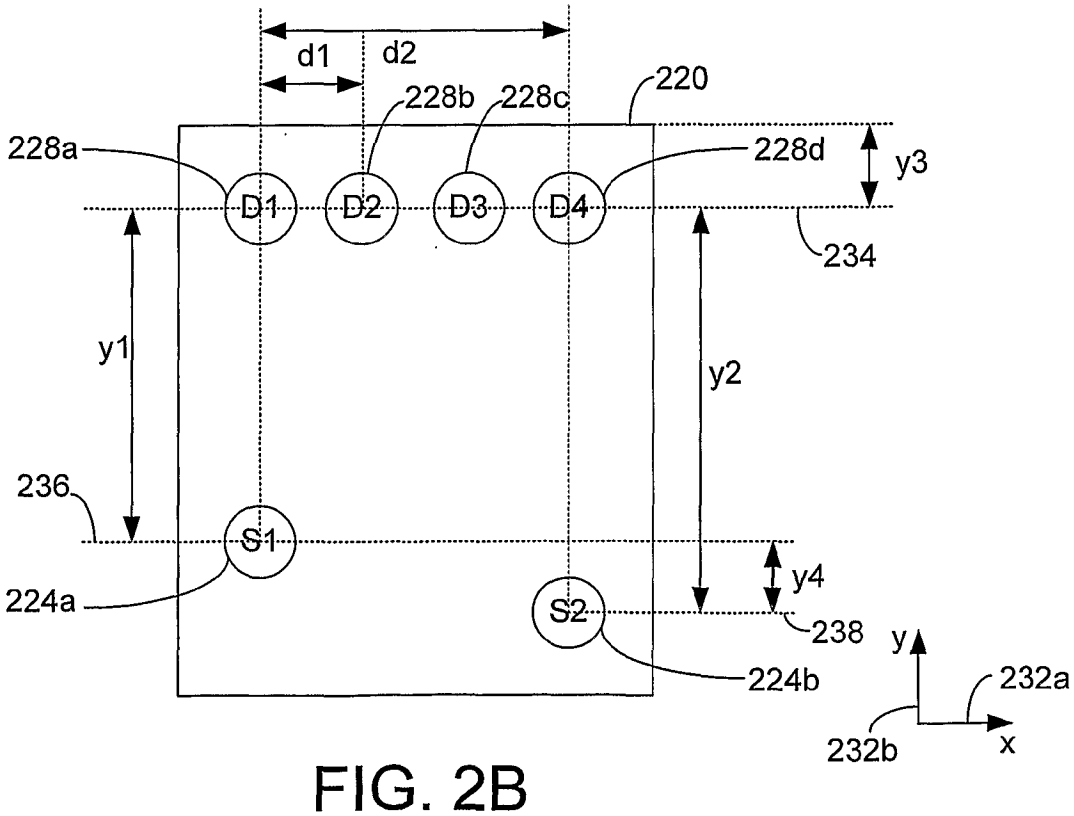
208b
D1
D2
214
y1
y2
216
S1
218
204a
S2
204b
200
y
212a
212b
x

FIG. 2A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d2
220
228b
228c
228a
228d
y3
D1
D2
D3
D4
234
y1
y2
236
S1
y4
224a
S2
238
224b
y
232a
232b
x

FIG. 2B

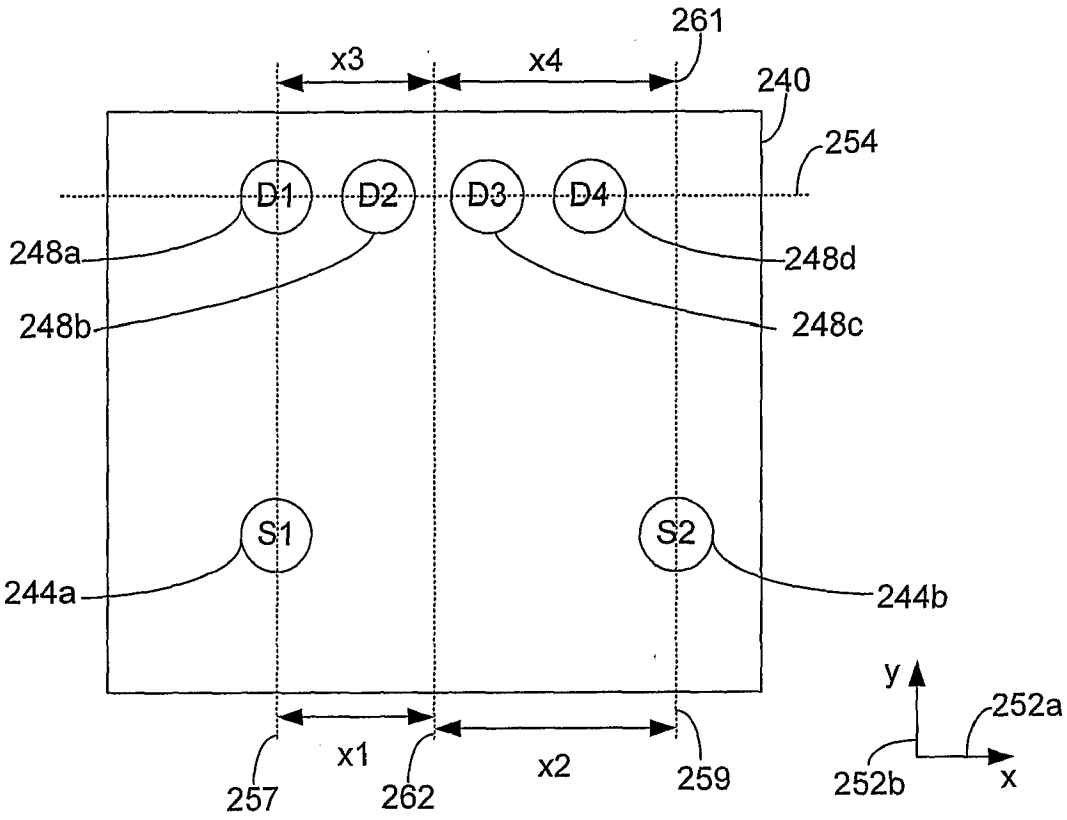
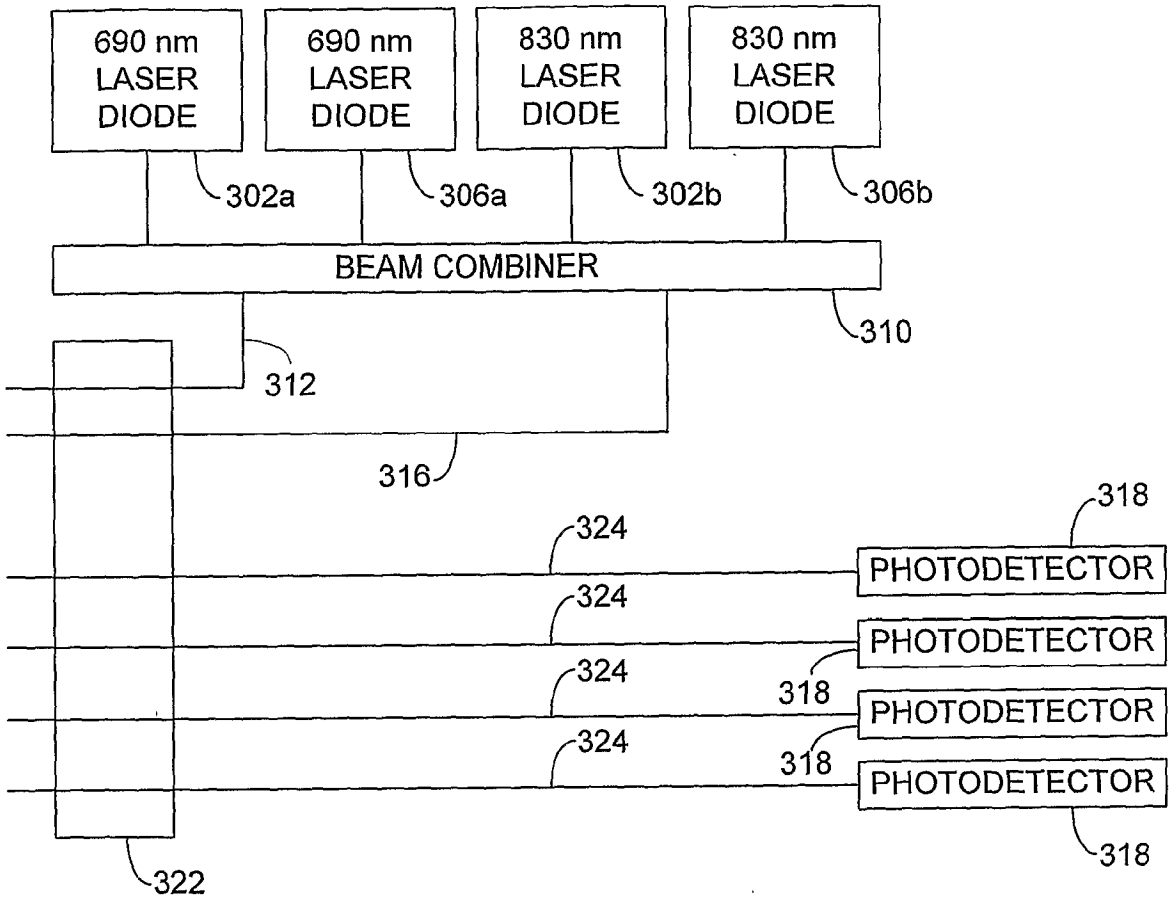

261
x3
x4
240
254
D1
D2
D3
D4
248a
248d
248b
248c
S1
S2
244a
244b
y
252a
x1
x2
257
262
259
252b
x

FIG. 2C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690 nm LASER DIODE
830 nm LASER DIODE
830 nm LASER DIODE
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306a
302b
306b
BEAM COMBINER
310
312
316
318
324
PHOTODETECTOR
322

FIG. 3

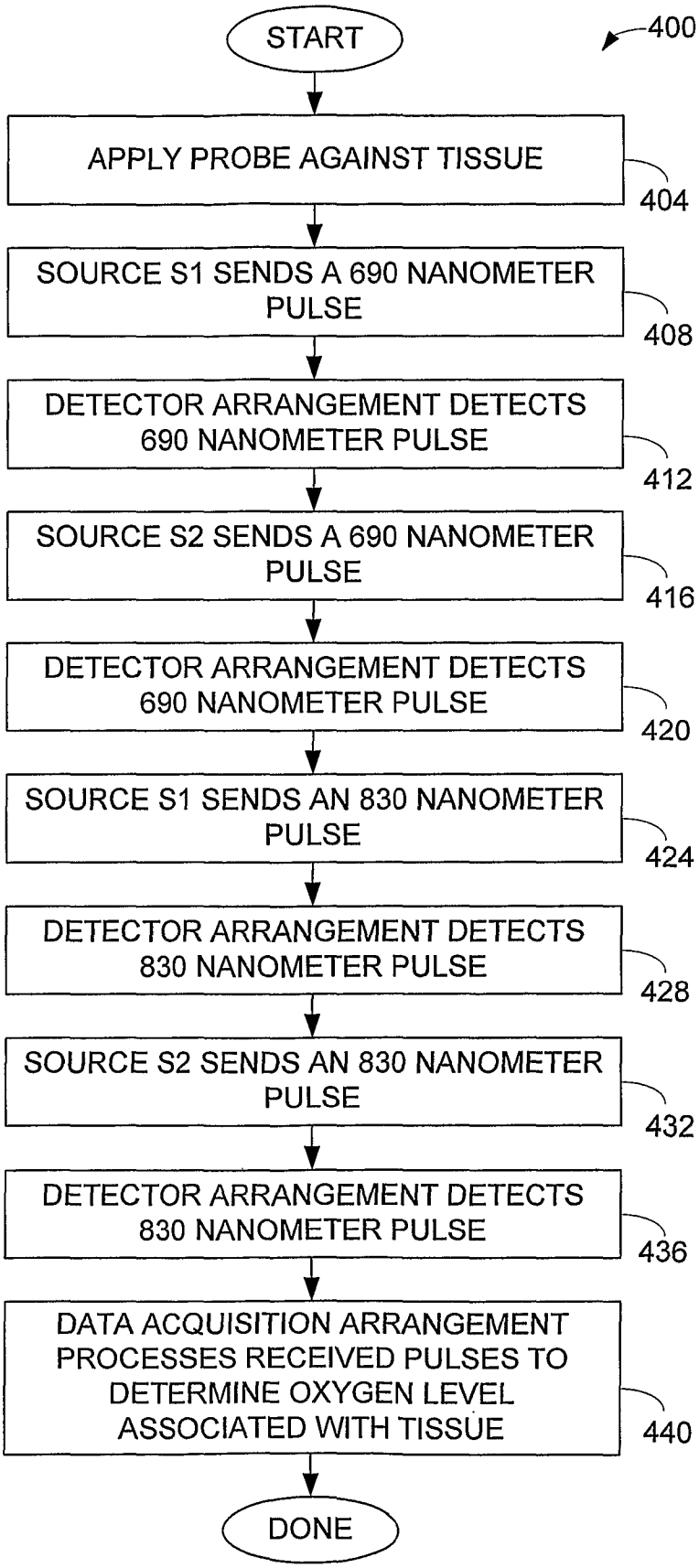
START
400
APPLY PROBE AGAINST TISSUE
404
SOURCE S1 SENDS A 690 NANOMETER PULSE
408
DETECTOR ARRANGEMENT DETECTS 690 NANOMETER PULSE
412
SOURCE S2 SENDS A 690 NANOMETER PULSE
416
DETECTOR ARRANGEMENT DETECTS 690 NANOMETER PULSE
420
SOURCE S1 SENDS AN 830 NANOMETER PULSE
424
DETECTOR ARRANGEMENT DETECTS 830 NANOMETER PULSE
428
SOURCE S2 SENDS AN 830 NANOMETER PULSE
432
DETECTOR ARRANGEMENT DETECTS 830 NANOMETER PULSE
436
DATA ACQUISITION ARRANGEMENT PROCESSES RECEIVED PULSES TO DETERMINE OXYGEN LEVEL ASSOCIATED WITH TISSUE
440
DONE

FIG. 4

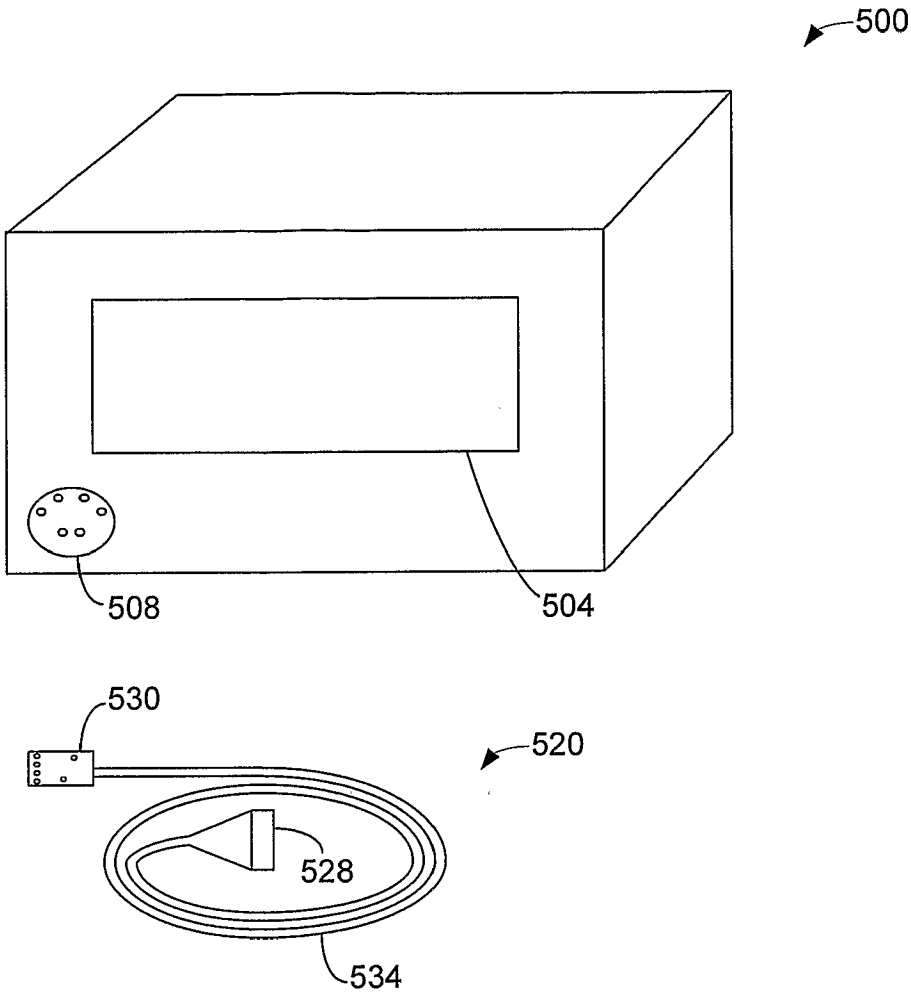

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 11 17 8840

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 00/28887 A (KRUG ALFONS [DE]) 25 May 2000 (2000-05-25) * pages 1,5,; figures * * page 11 - page 15 *	1-16	INV. A61B5/1455 A61B5/00 A61B5/024 G01N21/31
X	US 2003/144583 A1 (CHENG XUEFENG [US] ET AL) 31 July 2003 (2003-07-31) * paragraphs [0002], [0003], [0008], [0011], [0051], [0052], [0057], [0062], [0064], [0065], [0080]; figures *	1-16	
A	EP 0 663 591 A (ISS USA INC [US]; UNIV ILLINOIS [US] ISS USA INC [US]; TRUSTEES OF THE) 19 July 1995 (1995-07-19) * column 8, line 28 - column 10, line 19 * * column 12, line 45 - column 13, line 9; figures *	1-16	
A	WO 98/22018 A (UNIV SOUTH FLORIDA [US]) 28 May 1998 (1998-05-28) * page 4, line 1 - page 5, line 11; figures *	1-14	TECHNICAL FIELDS SEARCHED (IPC) A61B G01N
A	EP 1 518 494 A (HITACHI LTD [JP]) 30 March 2005 (2005-03-30) * paragraphs [0009], [0010], [0020], [0021], [0040] *	1-14	
A	WO 96/41566 A (CYBRO MEDICAL LTD [IL]; FINE ILYA [IL]; STERNBERG ALEXANDER [IL]; KATZ) 27 December 1996 (1996-12-27) * page 5, line 20 - page 7, line 7; figures * * page 14, line 26 - page 15, line 5 *	1-14	

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	21 October 2011	Mundakapadam, S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
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& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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European Patent Office
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EUROPEAN SEARCH REPORT

Application Number
EP 11 17 8840

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	EP 0 538 631 A1 (BOC HEALTH CARE [US] OHMEDA INC [US]) 28 April 1993 (1993-04-28) * claims; figure 1 * -----	1-16	

TECHNICAL FIELDS SEARCHED (IPC)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	21 October 2011	Mundakapadam, S

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 17 8840

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21-10-2011

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0028887 A	25-05-2000	AT 404110 T	15-08-2008
		CN 1326328 A	12-12-2001
		EP 1130998 A1	12-09-2001
		ES 2312220 T3	16-02-2009
		JP 4490587 B2	30-06-2010
		JP 2003517342 A	27-05-2003
		US 6859658 B1	22-02-2005
US 2003144583 A1	31-07-2003	US 2002019587 A1	14-02-2002
EP 0663591 A	19-07-1995	AT 219242 T	15-06-2002
		CA 2137878 A1	17-06-1995
		DE 69430791 D1	18-07-2002
		DE 69430791 T2	06-02-2003
		JP 3619969 B2	16-02-2005
		JP 8089500 A	09-04-1996
		US 5772587 A	30-06-1998
WO 9822018 A	28-05-1998	AU 5586998 A	10-06-1998
		US 6330468 B1	11-12-2001
		US 5830137 A	03-11-1998
EP 1518494 A	30-03-2005	CN 1600271 A	30-03-2005
		JP 3590047 B1	17-11-2004
		JP 2005095317 A	14-04-2005
		US 2005065415 A1	24-03-2005
WO 9641566 A	27-12-1996	AU 708051 B2	29-07-1999
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		DE 69631698 D1	01-04-2004
		DE 69631698 T2	29-07-2004
		EP 0957747 A2	24-11-1999
		JP H11507568 A	06-07-1999
		JP 3772189 B2	10-05-2006
		JP 3928972 B2	13-06-2007
		JP 2006051374 A	23-02-2006
		US 6031603 A	29-02-2000
EP 0538631 A1	28-04-1993	DE 69228515 D1	08-04-1999
		DE 69228515 T2	21-10-1999
		JP 5200018 A	10-08-1993
		US 5387122 A	07-02-1995
		US 5249576 A	05-10-1993

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

专利名称(译)	用于光学成像系统的光学探针		
公开(公告)号	EP2389862A1	公开(公告)日	2011-11-30
申请号	EP2011178840	申请日	2006-08-24
[标]申请(专利权)人(译)	维奥普蒂克斯公司		
申请(专利权)人(译)	VIOPTIX INC.		
当前申请(专利权)人(译)	VIOPTIX INC.		
[标]发明人	LASH ROBERT MAO JIAN MIN LIN QIONG		
发明人	LASH, ROBERT MAO, JIAN-MIN LIN, QIONG		
IPC分类号	A61B5/1455 A61B5/00 A61B5/024 G01N21/31		
CPC分类号	A61B5/14552 G01N21/3151		
优先权	11/162376 2005-09-08 US		
其他公开文献	EP2389862B1		
外部链接	Espacenet		

摘要(译)

公开了用于监测组织中的氧饱和度水平的方法和装置。根据本发明的一个方面，一种用于光学成像系统的传感器装置包括第一源结构，第二源结构和检测器装置。第一源结构提供第一光束，第二源结构提供第二光束。检测器装置包括具有中心点的检测器结构，并且在第一和第二光束被外表面反射之后接收第一和第二光束。检测器装置布置成限定穿过每个检测器结构的中心点的第一轴，并且从第一源结构的中心点到第一轴的距离不等于从第二源结构的中心点到第二源结构的中心点的距离。第一轴。

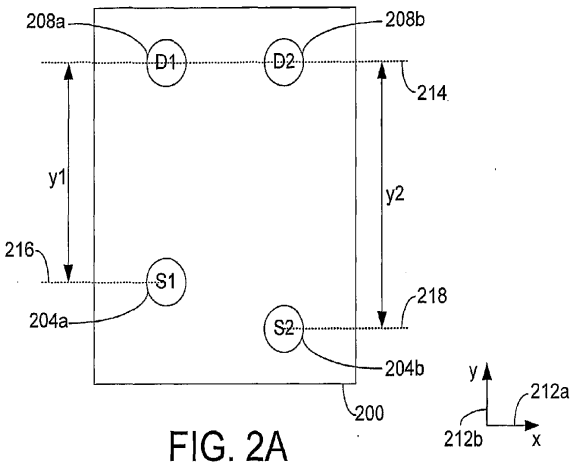

FIG. 2A