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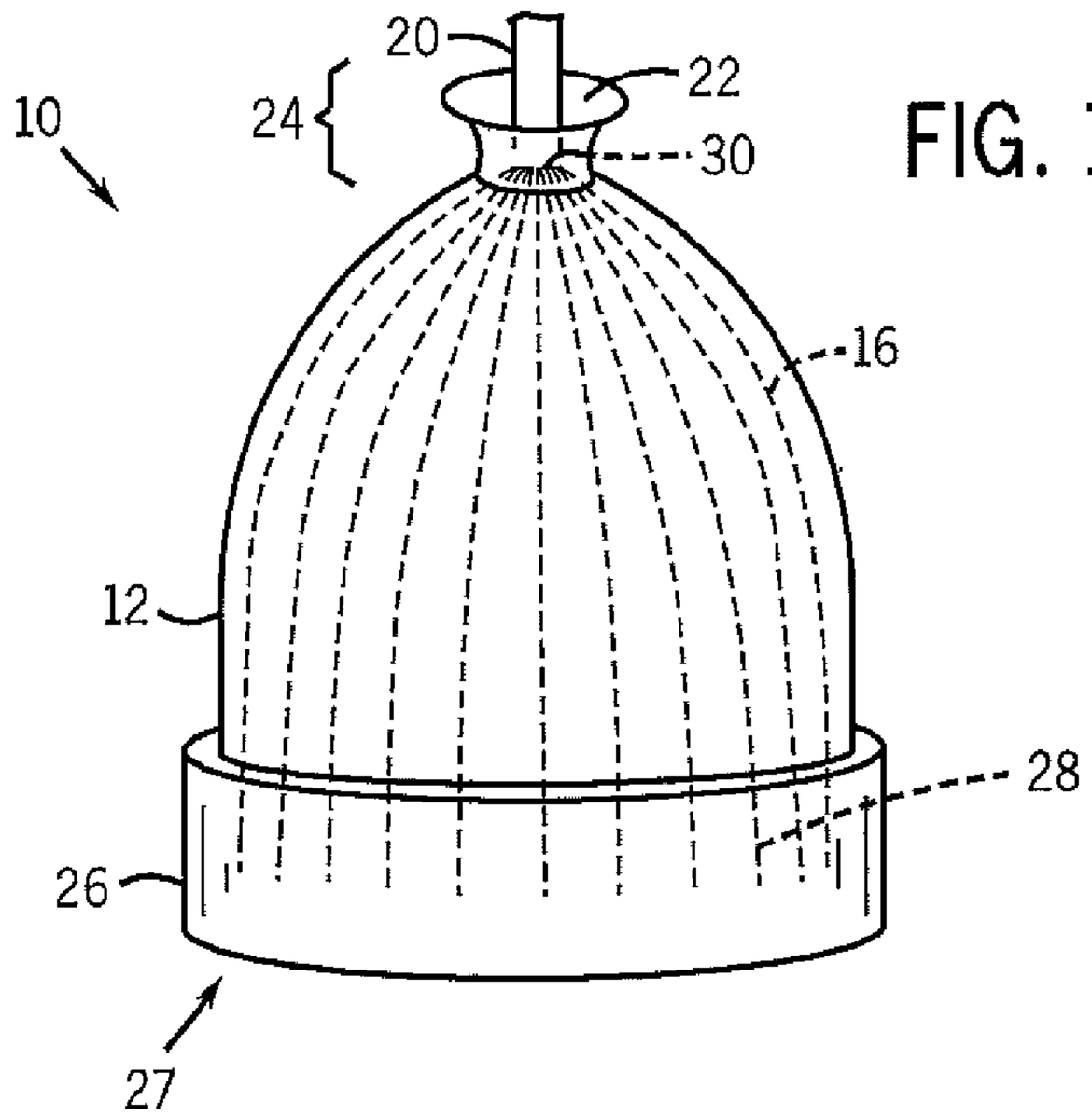

FIG. 1

(57) Abrégé/Abstract:
According to various embodiments, a hat-based or headband sensor assembly may include thin or flexible optical sensing components, such as optical fibers or ultra thin emitters or detectors. In embodiments, the sensor assembly may be a hat-based sensor that includes a gripping region, for example on the inside of the hat band, to help secure the hat to a patient's head.

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(54) Title: MEDICAL SENSOR WITH FLEXIBLE COMPONENTS AND TECHNIQUE FOR USING THE SAME

(57) Abstract: According to various embodiments, a hat-based (10) or headband (26) sensor assembly may include thin or flexible optical sensing components, such as optical fibers (16) or ultra thin emitters or detectors (44a/b). In embodiments, the sensor assembly may be a hat -based sensor that includes a gripping region (74), for example on the inside of the hat band, to help secure the hat to a patient's head.

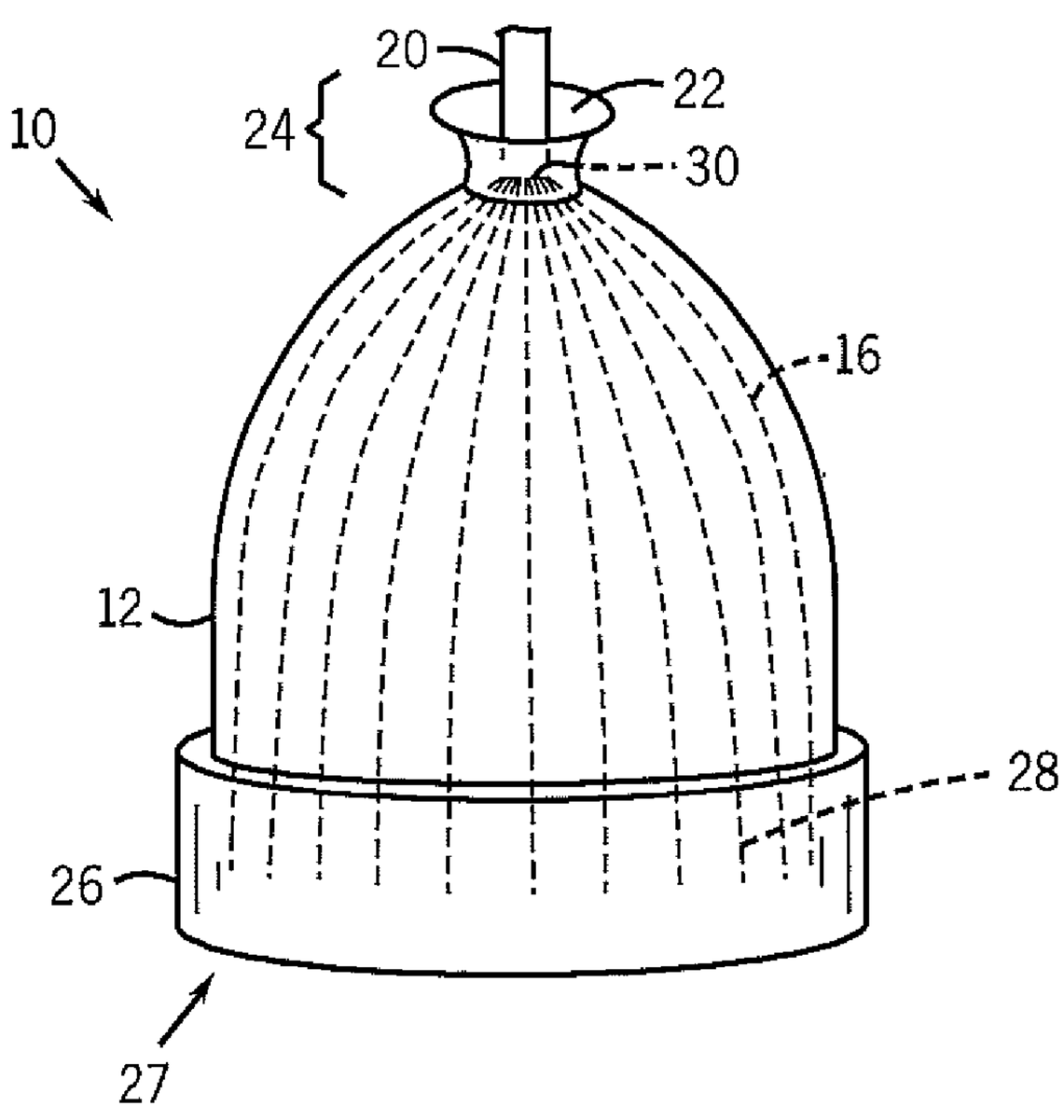

FIG. 1

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MEDICAL SENSOR WITH FLEXIBLE COMPONENTS AND TECHNIQUE FOR USING THE SAME

BACKGROUND

The present disclosure relates generally to medical devices and, more particularly, to sensors used for sensing physiological parameters of a patient.

This section is intended to introduce the reader to aspects of the art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

In the field of medicine, doctors often desire to monitor certain physiological characteristics of their patients. Accordingly, a wide variety of devices have been developed for monitoring many such physiological characteristics. Such devices provide doctors and other healthcare personnel with the information they need to provide the best possible healthcare for their patients. As a result, such monitoring devices have become an indispensable part of modern medicine.

One technique for monitoring certain physiological characteristics of a patient is commonly referred to as pulse oximetry, and the devices built based upon pulse oximetry techniques are commonly referred to as pulse oximeters. Pulse oximetry may be used to measure various blood flow characteristics, such as the blood-oxygen saturation of hemoglobin in arterial blood, the volume of individual blood pulsations supplying the tissue, and/or the rate of blood pulsations corresponding to each heartbeat of a patient. In fact, the "pulse" in pulse oximetry refers to the time varying amount of arterial blood in the tissue during each cardiac cycle.

Pulse oximeters typically utilize a non-invasive sensor that transmits light through a patient's tissue and that photoelectrically detects the absorption and/or scattering of the transmitted light in such tissue. One or more of the above physiological characteristics may then be calculated based upon the amount of light absorbed or scattered. More specifically, the light passed through the tissue is typically selected to be of one or more wavelengths that may be absorbed or scattered by the blood in an amount correlative to the amount of the blood constituent present in the blood. The amount of light absorbed and/or scattered may then be used to estimate the amount of blood constituent in the tissue using various algorithms.

Pulse oximetry readings involve placement of a sensor on a patient's tissue, typically via a lightly adhesive sensor, a clip-style sensor, or a sensor that may be fitted into a wearable garment, such as a hat or a headband. With regard to the latter, if the hat or headband is not closely fitted to the patient's tissue, ambient light may interfere with the sensor's light detection. Some outside light infiltration into the sensor may be avoided by fitting the sensor snugly against the patient's tissue. However, such a conforming fit may be difficult to achieve over a range of patient physiologies without adjustment or excessive attention on the part of medical personnel. Additionally, an overly tight fit may cause local exsanguination of the tissue around the sensor. Exsanguinated tissue, which is devoid of blood, may shunt the sensor light through the tissue, which may also affect measurement accuracy.

BRIEF DESCRIPTION OF THE DRAWINGS

Advantages of the disclosure may become apparent upon reading the following detailed description and upon reference to the drawings in which:

FIG. 1 illustrates a perspective view of a hat structure with multiple optical fibers for holding a medical sensor on a patient's tissue according to an embodiment;

FIG. 2 illustrates a perspective view of a headband-style sensor for holding a medical sensor on a patient's tissue according to an embodiment;

FIG. 3 is a cutaway view of the interior of a hat structure with optical sensing components sewn or otherwise attached directly to the band of the hat according to an embodiment;

FIG. 4 is a cutaway view of the interior of a hat structure with a recess in the hat band for holding optical sensing components according to an embodiment;

FIG. 5 is a cross-sectional view of a hat band with a gripping layer according to an embodiment;

FIG. 6 illustrates a pulse oximetry system coupled to a multi-parameter patient monitor and a sensor according to an embodiment; and

FIG. 7 is a block diagram of a pulse oximetry system according to an embodiment.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

One or more specific embodiments of the present disclosure will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

Medical sensors for applications utilizing spectrophotometry are provided therein that include optical components that conform closely to a patient's tissue. Such sensors may include sensors for pulse oximetry, tissue water fraction, tissue carbon dioxide, hematocrit, or glucose, or any combination thereof. In an

embodiment, a hat-based pulse medical sensor assembly for neonatal patients may be configured to provide a conforming fit without uncomfortable pressure on the tissue. Because the accuracy of spectrophotometric sensors, such as pulse oximetry sensors, may be improved when the sensor is directly in contact with the skin, it may be desirable to avoid stiff or inflexible electrical or optical components that may interfere with the fit of the hat.

Hence, provided herein are flexible, wearable sensing assemblies that include optical components that may be woven into the fabric of the wearable sensor or applied directly to the fabric of the without stiff backing materials. In an embodiment, such sensor assemblies may include optical fibers that are woven into a fabric of the sensor assembly to transmit light into a patient's tissue and return light that has passed through the tissue and is representative of a physiological constituent. Also provided herein are sensor assemblies that include optical component backing materials that are thin and/or highly flexible. Such thin and/or highly flexible materials may also provide the advantage of having gripping properties without being adhesive. Sensor assemblies may also include thin and flexible optical components, such as ultrathin light emitters and photodetectors. In embodiments, the sensor assemblies may include optical components that are flush or substantially flush with the sensor body. For example, a hat band may include a pocket in which the optical components may be placed so that the surface that contacts the tissue is generally smooth or planar.

In an embodiment, a medical sensor, such as a sensor for pulse oximetry, may be adapted for placement in a hat (for example, a neonatal stocking cap), a headband, or other wearable structure (*i.e.* a glove, a sock, a wristband) to apply the sensor on the body of the user.

FIG. 1 illustrates an embodiment of a sensor assembly **10** including a wearable structure, which may be a hat **12**, as shown in **FIG. 1**. The optical components of the sensor may include optical fibers **16** that transmit light from a light emitter. The optical fibers are woven into the fabric of the hat **12**. When the hat **12** is applied to the patient, the optical fibers come into contact with the skin and are able to transmit and receive light as part of a medical sensor assembly **10**.

As shown, the optical fibers **16** may be distributed throughout the hat, allowing for multiple sites of measurement. In embodiments, a monitor or downstream measurement device may receive signals related to multiple measurements from the sensor assembly **10** and may combine or otherwise analyze the results.

Also shown in **FIG. 1** is a cable **20** for providing an electrical/optical connection for the optical fibers **16** to downstream light emitter(s) and photodetector(s) (not shown). **FIG. 1** shows that the cable **20** is positioned through an opening **22** in the top **24** of the hat **12**. In an embodiment, the cable **20** may be adhered or otherwise constrained in the hat **12** so that the cable generally is positioned away from the hat **12** to avoid interfering with the patient's eyesight or bothering the patient.

The optical fibers **16** may be single fibers or fiber bundles. The fibers or fiber bundles **16** may be formed from relatively flexible materials, for example a transparent plastic, such as poly(methyl methacrylate) or polystyrene with a fluoropolymer cladding. Examples of optical fibers **16** include single-mode fibers, multi-mode fibers, photonic-crystal fibers, hollow-core fibers, polarization-maintaining fibers and dual-clad fibers. Typical diameters for optical fibers **16** may be 5 to 1,000 micrometers.

In one embodiment, an individual optical fiber **16** may serve to emit light into tissue and receive the light reflected back by the tissue. In other words, each individual fiber **16** may transmit emitted light and receive reflected light. In an embodiment, a fiber bundle may include fibers that are dedicated emitting fibers (i.e., optically connected to a light source) and dedicated detecting fibers (i.e., optically connected to a photodetector). A hat 12 may be woven from an optical fiber fabric, such as Luminex® Fabric (Luminex S.P.A., Italy). In one particular implementation, the optical fibers **16** may be spaced apart within the hat **12** so alternating fibers **16** are dedicated emitting fibers and dedicated detecting fibers. In such an implementation, the spacing of the fibers **16** may reflect appropriate emitter-detector spacing for pulse oximetry applications, such as at least about 1mm to at least about 14mm spacing. In embodiments, the spacing may be 1mm-

8mm or 2mm-6mm. For other types of medical sensors, such as water fraction sensors, the spacing distance may be larger or smaller, as appropriate.

In one implementation, the optical fibers **16** may be woven into the hat. For example, the optical fibers **16** may be woven such that generally run in the same direction, such as down the length of the hat from opening **22** towards hat band **26**. The distal ends **28** of the optical fibers **16** may terminate in the band **26**. It should be understood that a hat **12** as envisioned may not necessarily include a band **26**. In embodiments, the hat **12** may simply include a distal opening **27**, and the optical fibers **16** may terminate near or towards the distal opening **27**. The optical fibers **16** may be notched, terminated, scribed, or modified, for example by a cutter during the weaving process, at an appropriate location in the hat band **26**. At the top portion **24** of the hat **12**, the proximal ends **30** of the optical fibers **16** may be gathered within cable **20** or may otherwise optically connect to an emitter and photodetector. During the weaving process, the proximal ends **30** of the optical fibers **16** may be left loose so that they may be later incorporated into the cable **20** or other optical connector.

While hat-based sensor assemblies **10** may generally be used on neonatal patients, adult patients may more typically wear forehead sensors that are applied directly to the forehead or sensors that are integrated into a headband. Hat-based sensors may be designed to apply light pressure to the head of an infant. In contrast, headband-based sensors may be designed to apply more pressure to the more robust tissue of an adult, which may facilitate a more conforming fit of the sensor and more accurate measurements. **FIG. 2** illustrates an embodiment of a headband-based sensor assembly **40**. The headband-based sensor assembly **40** may include a strap or band **42** that may be fitted around a patient's forehead tissue to bring the optical fibers **16** with the tissue. The optical fibers **16** may be woven into the fabric of the band **42**. In one embodiment, the band **42** may include indicators to position the distal ends **44a** and **44b** of the optical fibers **16** on a particular location on the patient's forehead, for example to position the distal ends **44a** and **44b** on the lower forehead region, above the eyebrow, above and predominantly lateral to or centered over the iris. The location of the distal ends **44a** and **44b**

within the band **42** facilitate appropriate placement of the optical sensing components in the desired forehead location by a user. In addition, the headband-based sensor assembly **40** may include one or more alignment indices **42,** for example a printed design on the band **42** visible to the caregiver, to assist in the proper placement of the distal ends **44a** and **44b** of the optical fibers **16** on the patient's forehead.

In addition to using optical fibers **16** to deliver light to a patient's tissue, similar advantages (e.g., flexible optical components) may be realized by fabricating the optical components, without stiff backing materials. In an embodiment shown in **FIG. 3**, a hat assembly **58** may include sensing components, e.g., an emitter **60** and a detector **62**, that may be applied directly to the fabric surface of the hat **12**. The emitter **60** and the detector **62** may be adhered to the interior, tissue-contacting, surface **64** of the hat band. In addition, leads **56** and **58** connecting the emitter **60** and the detector **62** to the cable **20** may be adhered to or woven into the fabric of the hat **12**. In embodiments in which additional electrical shielding may be desirable, the emitter **60** and the detector **62** may be glued or otherwise adhered onto thin wire mesh or other thin and flexible backings **66** and **68**, respectively, which may in turn be adhered to the band **26** of the hat **12**. In embodiments, flexible backings **66** and **68** may be formed from any thin and flexible material, for example any flexible material less than 5mm in thickness, less than 1mm in thickness, or less than 0.5 mm in thickness. The material may be sufficiently flexible to conform easily to a patient's tissue.

In certain embodiments, the sensing components themselves may be formed from thin and/or flexible materials. For example, leads **56** and **58** may be formed from thin and flexible shielded wires. The emitter **60** may be an ultra-thin LED, such as a 0.25mm LED, available from Kingbright (City of Industry, California). The detector **62** may be an ultra thin-film metal-semiconductor-metal (MSM) photodetector. In embodiments, the emitter **60** and the detector **62** may protrude less than about 1mm, or less than about 0.5mm from the interior surface **64** of the hat band **26**. In certain embodiments, the emitter **60** and the detector **62**

may protrude about 0.25mm to about 1mm from the interior surface **64** of the hat band **26**.

A sensor assembly may also include structures, such as a pocket in the fabric, to allow the sensing components to lie flush or substantially flush against the interior surface of the hat band, which may facilitate a conforming fit against the tissue. In turn, this conforming fit may improve measurement accuracy, for example by reducing light being shunted from an emitter **60** to a detector **62**. As shown in **FIG. 4**, a hat assembly **70** may include a buttonhole or other pocket **76** formed on the interior surface **64** of the hat band **26** that may be sized and shaped to accommodate the emitter **60** and the detector **62**. In such embodiments, the emitter **60** and the detector **62** may be disposed on a thin and flexible backing, such as a fabric or paper backing **78** that is sized and shaped to fit into pocket **76** and may provide shielding to the emitter **60** and the detector **62**. It should be understood that the pocket **76** may be sufficiently deep so that the emitter **60** and the detector **62** may not substantially protrude from the interior surface **64** of the hat band **26**. In embodiments, the backing **78** may assist in positioning the emitter **60** and the detector **62** to lie flush with the interior surface **64** of the hat band **26**.

The sensor assemblies as provided may include addition features to facilitate a secure and comfortable fit while also maintaining relatively flexible arrangements of optical sensing components. A sensor assembly **72** may include a gripping portion **74**,which may be a layer applied to the interior of the hat band **26**, as shown in cross-section in **FIG. 5**. The emitter **60** and the detector **62** may be adhered or otherwise secured to the gripping portion **74**. The gripping portion **74** may be applied to the interior of a hat band **26** such that the tissue-contacting surface **76** of the gripping portion **74** may facilitate holding the sensor assembly **72** on the tissue. For example, a suitable gripping portion **74** may be made of plastic, rubber, silicone, vinyl, or woven material. In an embodiment, the gripping portion may be a relatively thin, flexible material such as Super Grip® Easy Liner® (Henkel) that is disposed on the interior of the hat **12**, such as on the hat band **26**.

The gripping portion **74** may be thin and highly flexible, while also having properties such as a high coefficient of friction that may help hold the emitter **60**

and the detector **62** in place. In certain embodiments, the gripping portion **74** is formed from a material that has a relatively large static coefficient of friction. A material with a large static coefficient of friction helps to keep sensor stable relative to the skin as a patient moves. The static coefficient of friction of a material may be tested using the following procedure: (1) Attach a protractor to a vertical wall with the center in line with the edge of a table. (2) Set up a stop block at the edge of the table to act as a pivot point for a glass plate. (3) Place the glass plate flat on the table with one edge along the edge of the table, up against the stop block. (4) Place a test sample of the material on the glass plate. (5) Lift the free edge of the glass plate until the test sample just starts to slip. (6) Record angle at which slippage first occurred. This angle is the angle of repose. Then calculate the coefficient of friction, which is the tangent of the angle of repose. The static coefficient of friction for gripping portion **74** may greater than 10. In certain embodiments, the static coefficient of friction for gripping portion **74** may be greater than 100. The gripping portion **74** may be a material that has a high static coefficient of friction relative to glass, such as polyvinyl chloride (PVC) foam. In embodiments, it may be desirable to calculate a static coefficient of friction of a material relative to a patient's skin. In certain embodiment, the gripping portion **74** has a static coefficient of friction greater than 5 with respect to a patient's skin

The foregoing sensors and sensor assemblies provided herein may be used in conjunction with any suitable medical device. A sensor or sensor assembly, illustrated generically as a sensor assembly **10**, may be used in conjunction with a pulse oximetry monitor **90**, as illustrated in **FIG. 6**. It should be appreciated that the cable **20** of the sensor assembly **10** may be coupled to the monitor **90** or it may be coupled to a transmission device to facilitate wireless transmission between the sensor assembly **10** and the monitor **90**. The monitor **90** may be any suitable pulse oximeter, such as those available from Nellcor Puritan Bennett LLC. Furthermore, to upgrade conventional pulse oximetry provided by the monitor **90** to provide additional functions, the monitor **90** may be coupled to a multi-parameter patient monitor **92** via a cable **94** connected to a sensor input port or via a cable **96** connected to a digital communication port.

FIG. 7 is a block diagram of an embodiment of a monitor **90** that may be configured to implement the embodiments of the present disclosure. Light from optical fiber **16** (or, in embodiments in which optical fibers **16** are not used, light directly from emitter **60**) may pass into a blood perfused tissue, and may be scattered, and then detected by detector **62**, which may be coupled to one or more optical fibers **16**. A sensor assembly **10** including optical fibers **16** (or, in embodiments, an emitter **60** and a detector **62**) may also contain an encoder **100** which may be capable of providing signals indicative of the wavelength(s) of light source **60** to allow the oximeter to select appropriate calibration coefficients for calculating oxygen saturation. The encoder **100** may, in an embodiment, be a resistor or may be a storage device, such as a memory.

In an embodiment, the sensor assembly **10** may be connected to a pulse oximetry monitor **90**. The monitor **90** may include a microprocessor **102** coupled to an internal bus **104**. Also connected to the bus may be a RAM memory **106** and a display **108**. A time processing unit (TPU) **110** may provide timing control signals to light drive circuitry **112**, which controls when the emitter **60** is activated, and if multiple light sources are used, the multiplexed timing for the different light sources. TPU **110** may also control the gating-in of signals from detector **62** through an amplifier **113** and a switching circuit **114**. These signals are sampled at the proper time, depending at least in part upon which of multiple light sources is activated, if multiple light sources are used. The received signal from the detector **62** may be passed through an amplifier **116**, a low pass filter **118**, and an analog-to-digital converter **120**. The digital data may then be stored in a queued serial module (QSM) **122**, for later downloading to RAM **106** or ROM **126** as QSM **122** fills up.

In an embodiment, based at least in part upon the received signals corresponding to the light received by detector **62**, microprocessor **122** may calculate the oxygen saturation using any suitable algorithm. Such algorithms may use coefficients, which may be empirically determined, and may correspond to the wavelengths of light used. The algorithms may be stored in a ROM **126** and accessed and operated according to microprocessor **122** instructions. For example,

the encoder **100** may communicate with decoder **128** to allow the microprocessor **122** to determine the appropriate coefficients.

In an embodiment of a two-wavelength system, the particular set of coefficients chosen for any pair of wavelength spectra may be determined by a value indicated by the encoder **100** corresponding to a particular light source in a particular sensor assembly **10**. In one embodiment, multiple resistor values may be assigned to select different sets of coefficients. In another embodiment, the same resistors are used to select from among the coefficients appropriate for an infrared source paired with either a near red source or far red source. The selection between whether the near red or far red set will be chosen can be selected with a control input from control inputs **134**. Control inputs **134** may be, for instance, a switch on the pulse oximeter, a keyboard, or a port providing instructions from a remote host computer. Furthermore, any number of methods or algorithms may be used to determine a patient's pulse rate, oxygen saturation or any other desired physiological parameter.

The sensor assembly **10** may be connected to or include an emitter **60** and a detector **62** that may be of any suitable type. For example, the emitter **60** may be one or more light emitting diodes adapted to transmit one or more wavelengths of light in the red to infrared range, and the detector **62** may one or more photodetectors selected to receive light in the range or ranges emitted from the emitter **60**. Alternatively, an emitter **60** may also be a laser diode or a vertical cavity surface emitting laser (VCSEL). Alternatively, a sensor assembly **10** may sense light detected from the tissue is at a different wavelength from the light emitted into the tissue. Such sensors may be adapted to sense fluorescence, phosphorescence, Raman scattering, Rayleigh scattering and multi-photon events or photoacoustic effects.

For pulse oximetry applications using either transmission or reflectance type sensors the oxygen saturation of the patient's arterial blood may be determined using two or more wavelengths of light, most commonly red and near infrared wavelengths. Similarly, in other applications, a tissue water fraction (or other body fluid related metric) or a concentration of one or more biochemical components in

an aqueous environment may be measured using two or more wavelengths of light, most commonly near infrared wavelengths between about 1,000 nm to about 2,500 nm. It should be understood that, as used herein, the term "light" may refer to one or more of ultrasound, radio, microwave, millimeter wave, infrared, visible, ultraviolet, gamma ray or X-ray electromagnetic radiation, and may also include any wavelength within the radio, microwave, infrared, visible, ultraviolet, or X-ray spectra.

Reflectance type sensors also operate by emitting light into the tissue and detecting the light that is transmitted and scattered by the tissue. However, reflectance type sensors include an emitter **60** and detector **62** that are typically placed on the same side of the sensor site. Alternatively, side-by-side optical fibers **16** or a single multi-mode optical fiber **16** may be used for reflectance measurements. For example, a reflectance type sensor may be placed on a patient's fingertip or forehead such that the emitter **60** and detector **62** lie side-by-side. Reflectance type sensors detect light photons that are scattered back to the detector **62**. A sensor assembly **10** may also be a "transflectance" sensor, such as a sensor that may subtend a portion of a baby's heel. In embodiments, contemplated sensor assemblies may be sock-type or glove-type assemblies.

While the disclosure may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the embodiments provided herein are not intended to be limited to the particular forms disclosed. Indeed, the disclosed embodiments may not only be applied to measurements of blood oxygen saturation, but these techniques may also be utilized for the measurement and/or analysis of other blood constituents. For example, using the same, different, or additional wavelengths, the present techniques may be utilized for the measurement and/or analysis of carboxyhemoglobin, met-hemoglobin, total hemoglobin, fractional hemoglobin, intravascular dyes, and/or water content. Rather, the various embodiments may cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure as defined by the following appended claims.

CLAIMS

What is claimed is:

1. An apparatus comprising:

a sensor body configured to be applied to a patient's head, foot, or hand;

a first optical fiber woven into the sensor body, wherein the first optical fiber is configured to transmit a light into a tissue region of the patient; and

a second optical fiber woven into the sensor body, wherein the second optical fiber is configured to transmit the light from the tissues region to a detector.

2. The apparatus of claim 1, wherein the sensor body comprises one of a stocking cap, a headband, a sock, or a glove.

3. The apparatus of claim 1, wherein the sensor body comprises a stocking cap and wherein the first optical fiber and the second optical fiber terminate in a band region of the stocking cap.

4. The apparatus of claim 3, comprising a cable extending through an opening in a top portion of the stocking cap, wherein the cable is coupled to the first optical fiber and the second optical fiber.

5. The apparatus of claim 1, wherein the first optical fiber is configured to emit light of a first wavelength of 600-750nm and a second wavelength of about 850-1000nm.

6. The apparatus of claim 1, comprising a gripping portion disposed on a tissue-contacting surface of the sensor body.

7. The apparatus of claim 6, wherein the gripping portion has a static coefficient of friction greater than 10.

8. The apparatus of claim 6, wherein the gripping portion is disposed on an interior surface interior of a band of the stocking cap.

9. The apparatus of claim 1, where the first and second optical fibers are spaced from about 1mm to about 14mm apart.

10. A pulse oximetry system comprising:

a pulse oximetry monitor; and

a sensor assembly capable of being operatively coupled to the monitor, the sensor assembly comprising:

a structure capable of being applied to a patient's head;

a first plurality of optical fibers woven into the structure, wherein the first plurality of optical fibers are configured to emit light into a respective plurality locations on the patient's head; and

a second plurality of optical fibers woven into the stocking cap, wherein the second plurality of optical fibers are configured to detect the light.

11. The system, as set forth in claim 10, wherein the structure comprises a stocking cap capable of being placed on the head of a neonate.

12. The system, as set forth in claim 10, where the respective plurality of locations comprises one or more locations on the forehead located above an eye.

13. The system, as set forth in claim 10, where the plurality of optical fibers terminate such that respective ends of the plurality of fibers substantially encircle a band or a distal opening of a stocking cap.

14. A sensor comprising:

a fabric or woven stocking cap;

a gripping portion disposed on the stocking cap comprising a tissue-contacting surface;

an emitter disposed on the gripping portion, wherein the emitter is configured to emit a light into a forehead region of the patient's head; and

a detector disposed on the gripping portion, wherein the detector is configured to detect the light.

15. The sensor of 14, wherein the emitter and the detector protrude less than 1mm from the tissue-contacting surface of the stocking cap.

16. The sensor of 14, wherein the gripping portion has a static coefficient of friction greater than 10.

17. The sensor of 14, wherein the gripping portion is disposed on an interior surface of a band of the stocking cap.

18. The sensor of 14, wherein the emitter and the detector are substantially flush with the tissue-contacting surface of the stocking cap.

19. The sensor of 14, wherein the emitter and the detector protrude less than 0.5mm from the tissue-contacting surface of the stocking cap.

20. The sensor of 14, comprising a cable extending through an opening in a top portion of the stocking cap, wherein the cable is coupled to the first optical fiber and the second optical fiber.

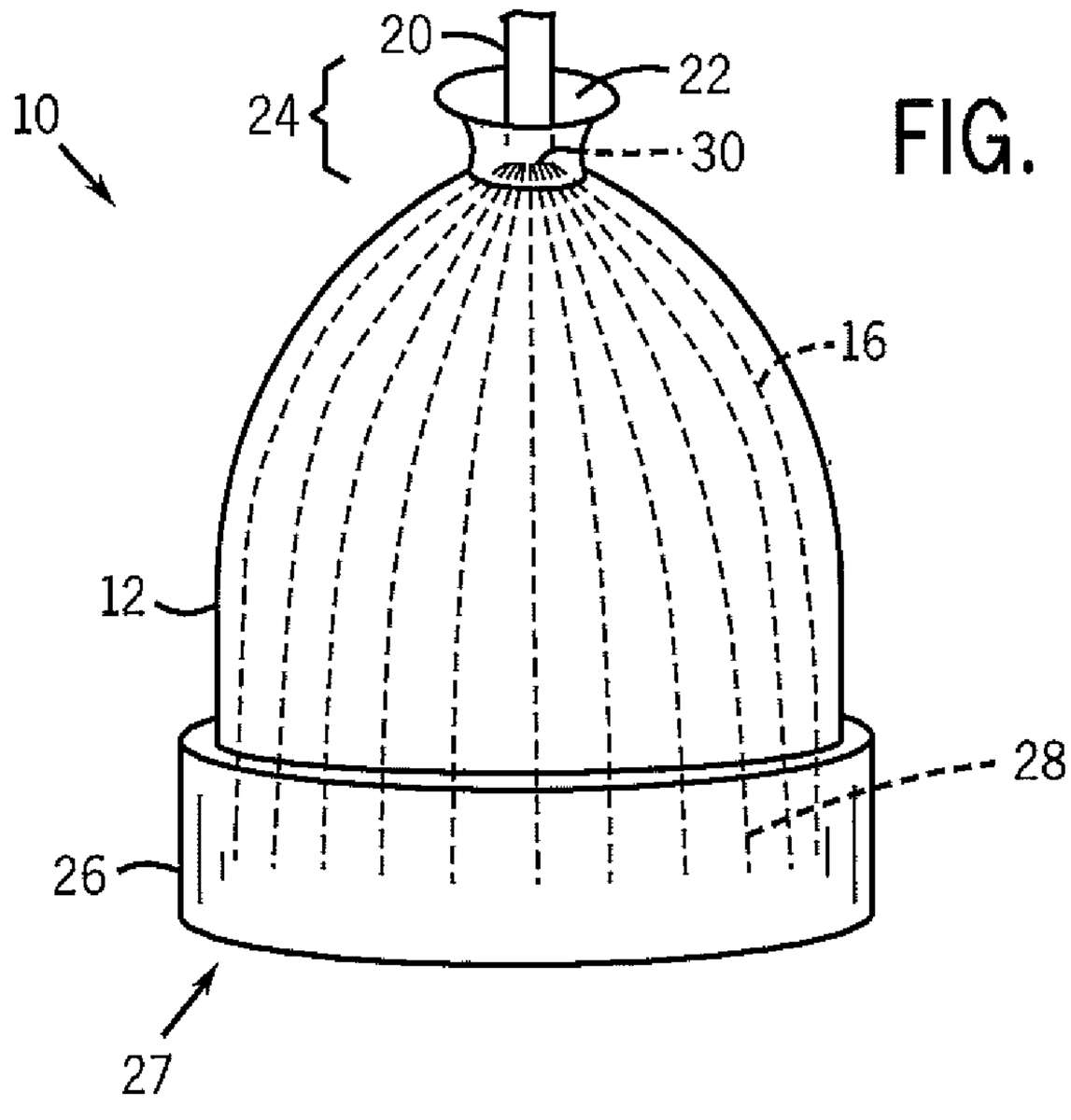

FIG. 1

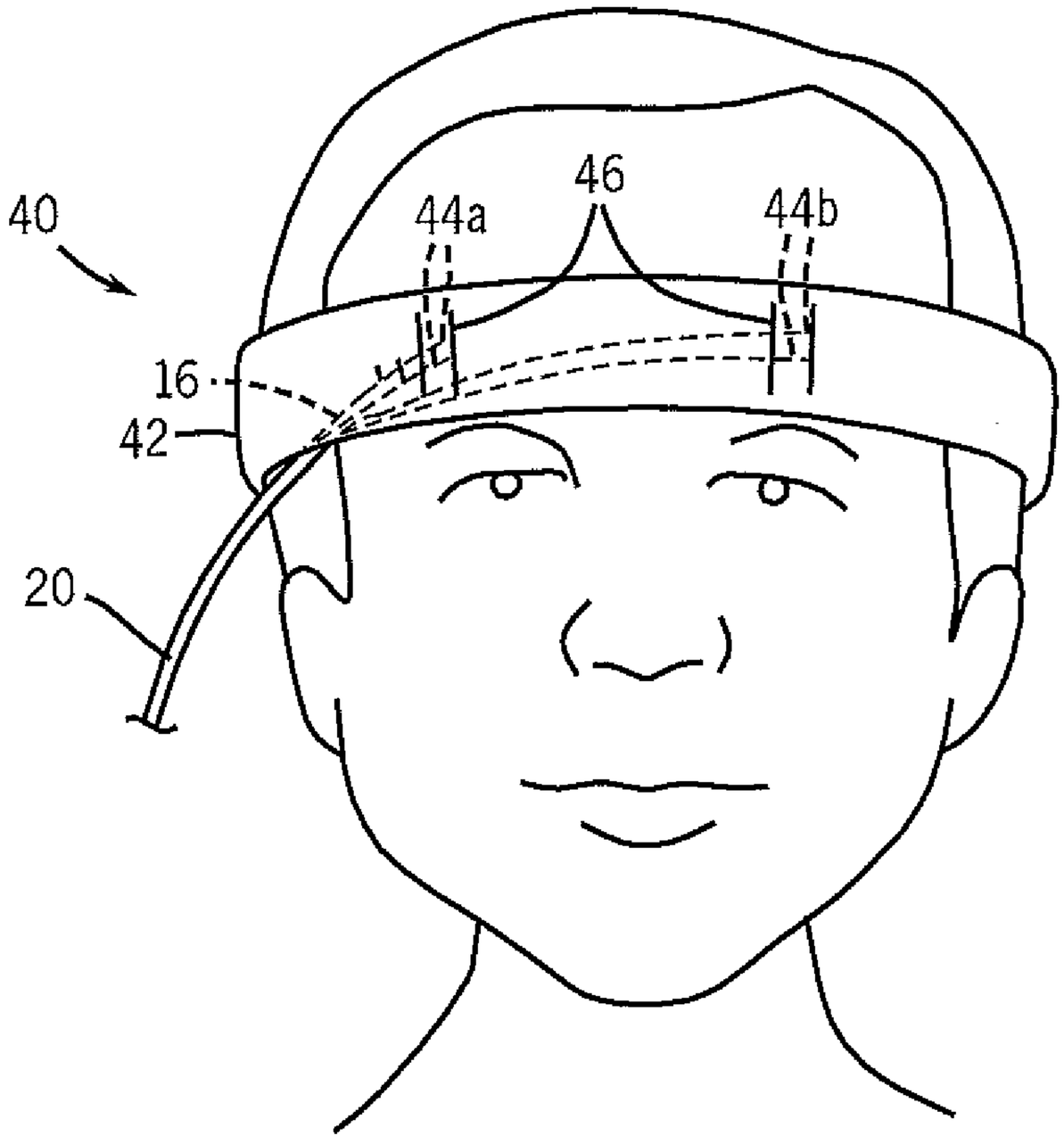

FIG. 2

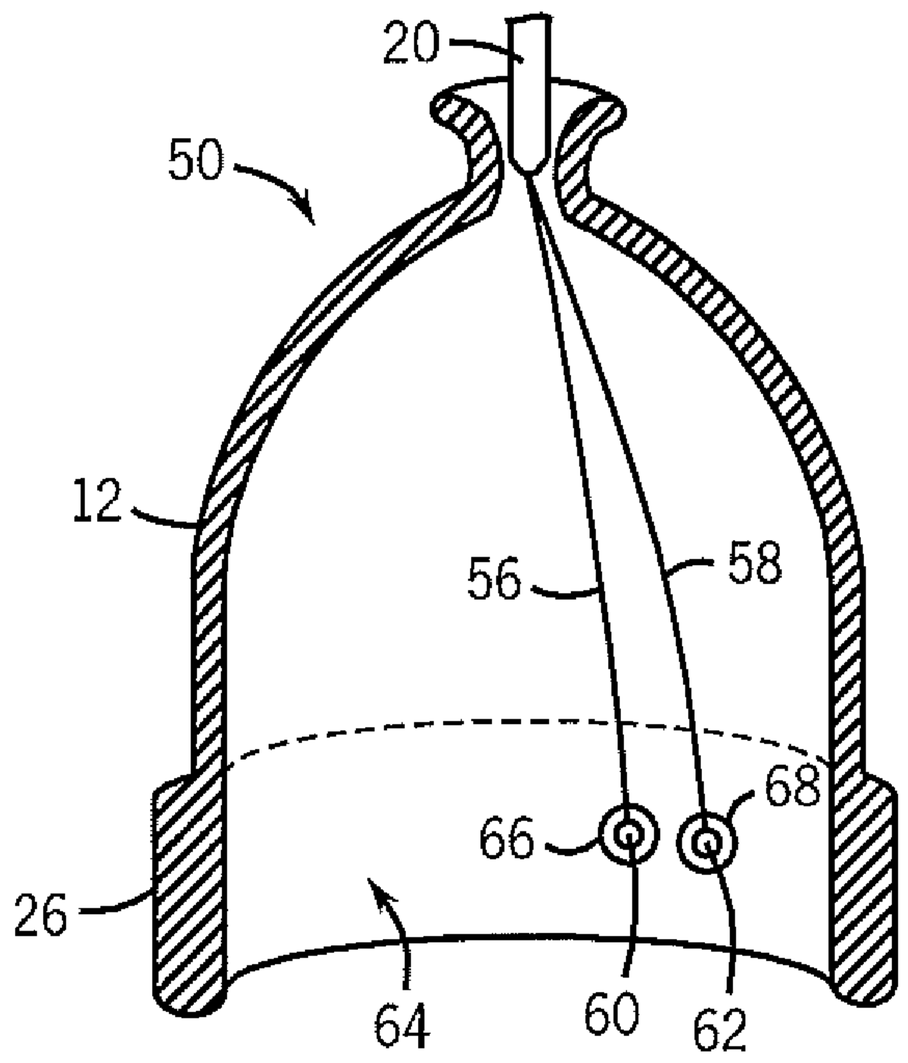

FIG. 3

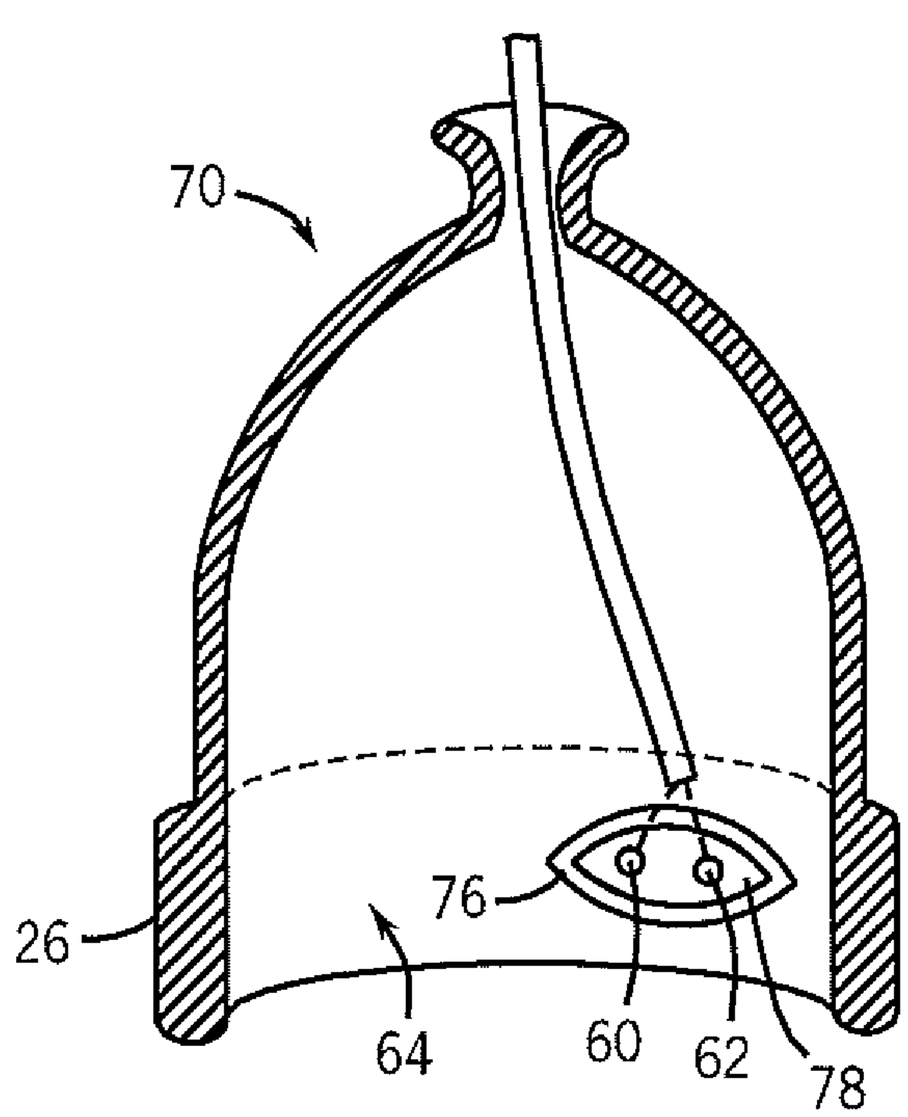

FIG. 4

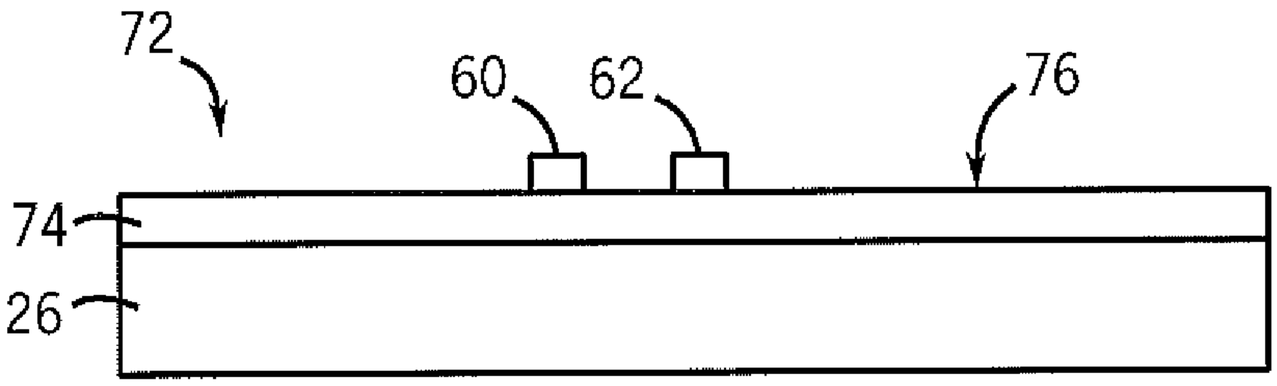

FIG. 5

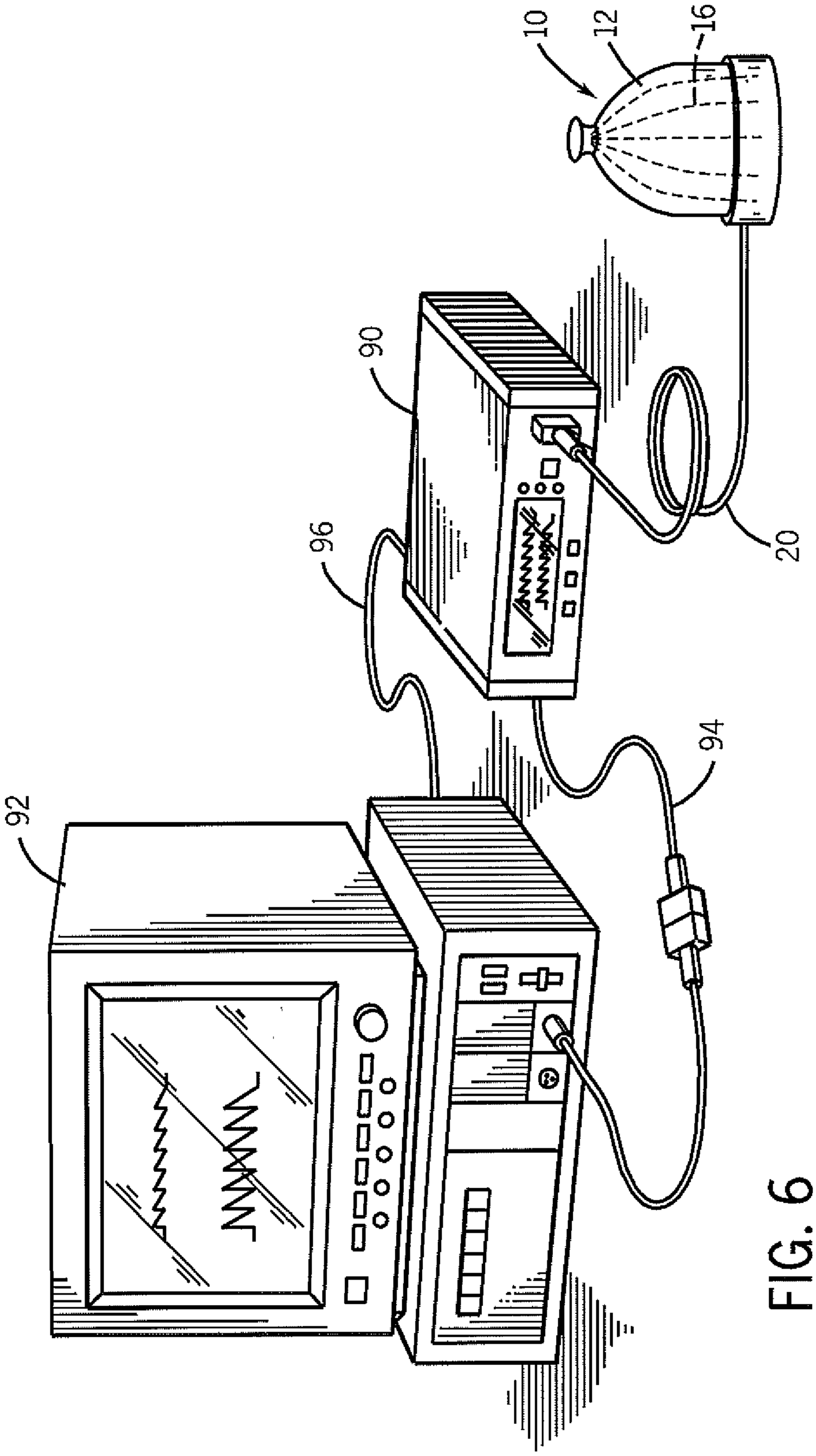

FIG. 6

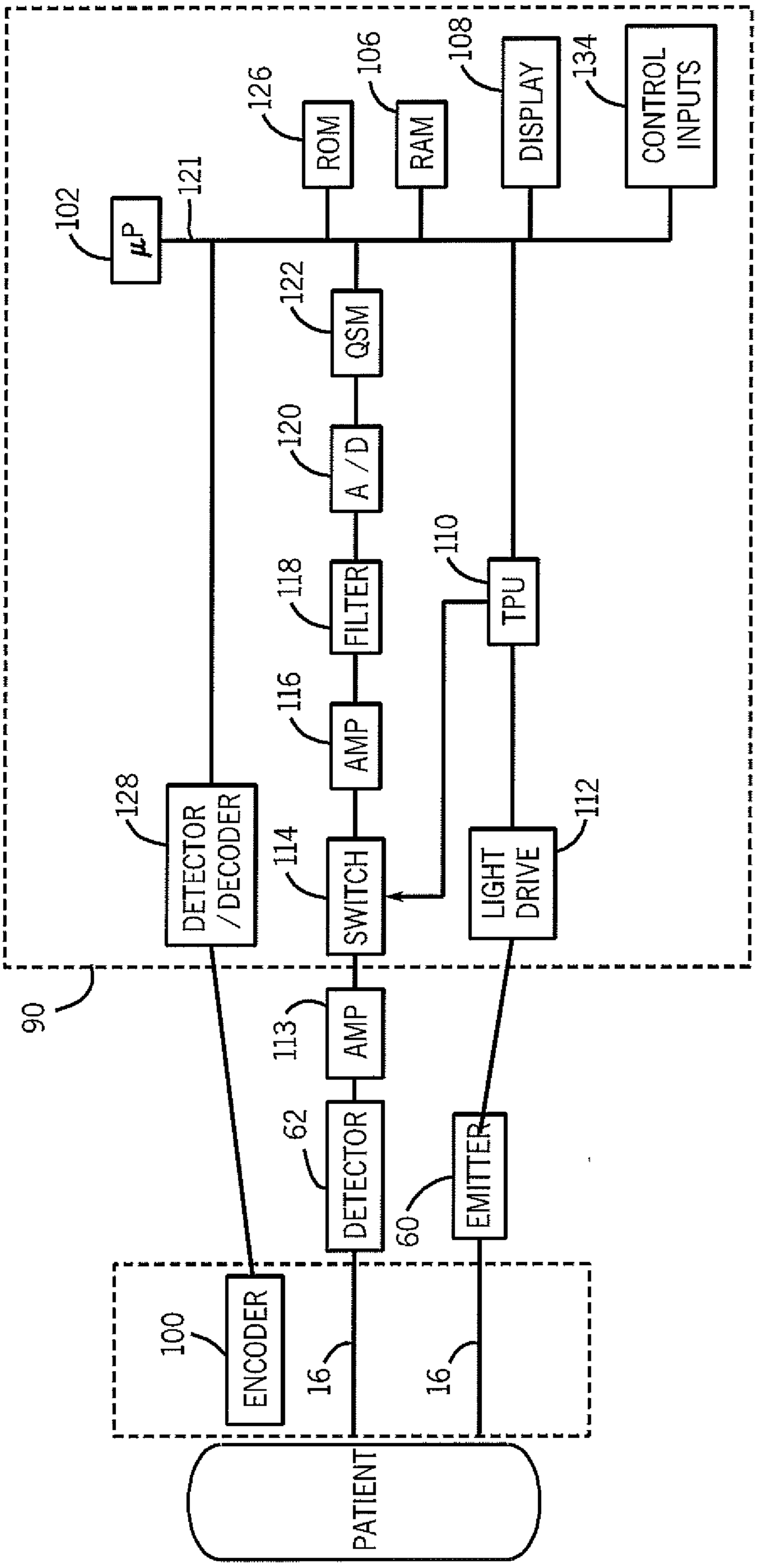
102
μP
121
126
ROM
106
RAM
108
DISPLAY
134
CONTROL INPUTS
122
124
QSM
120
A / D
118
FILTER
110
TPU
116
AMP
128
DETECTOR /DECODER
114
SWITCH
112
LIGHT DRIVE
90
113
AMP
62
DETECTOR
60
EMITTER
100
ENCODER
16
16
PATIENT

FIG. 7

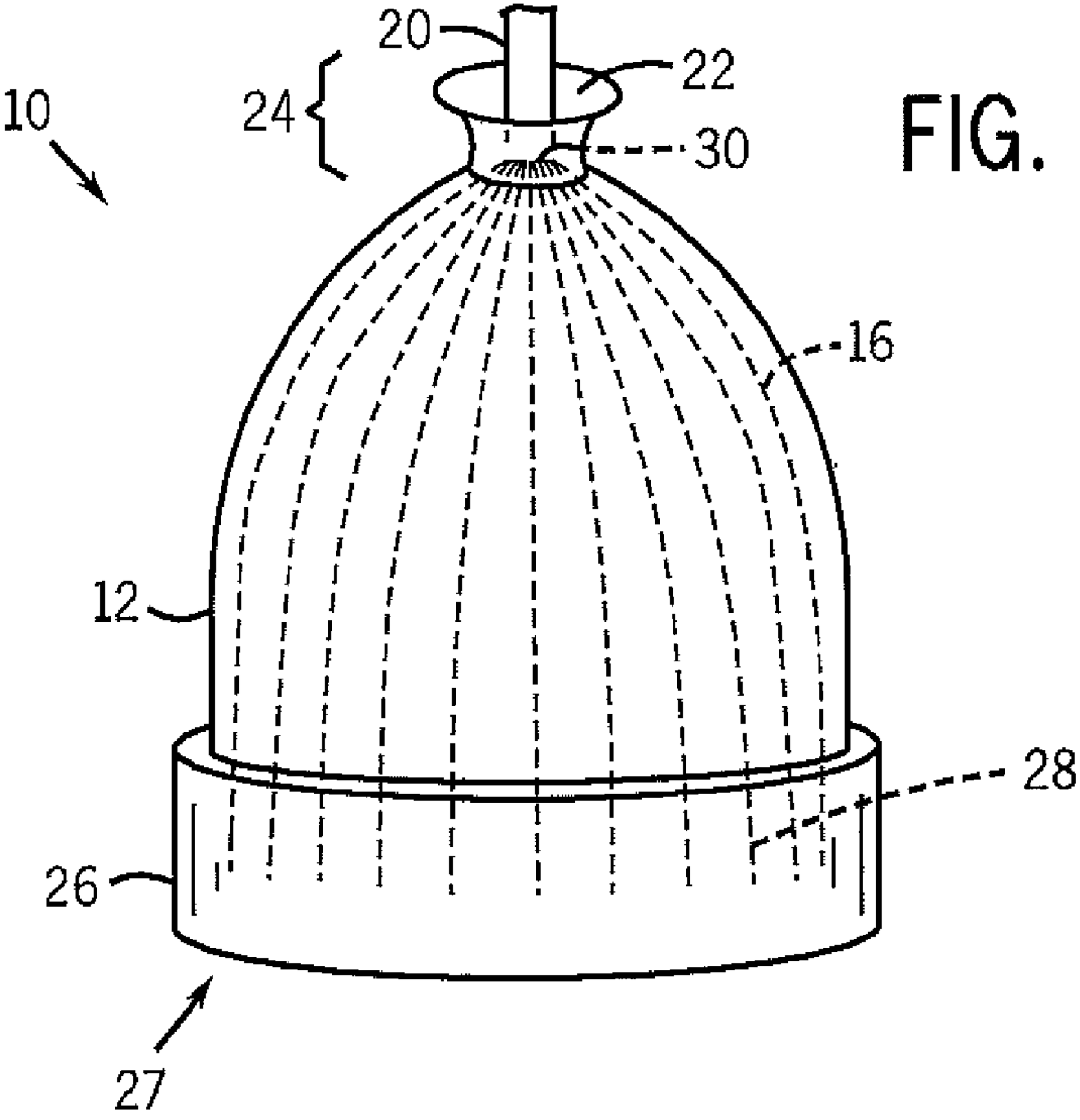

FIG. 1