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(54) **NON-INVASIVE GLUCOSE MONITORING SYSTEM**

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(52) **U.S. Cl.**

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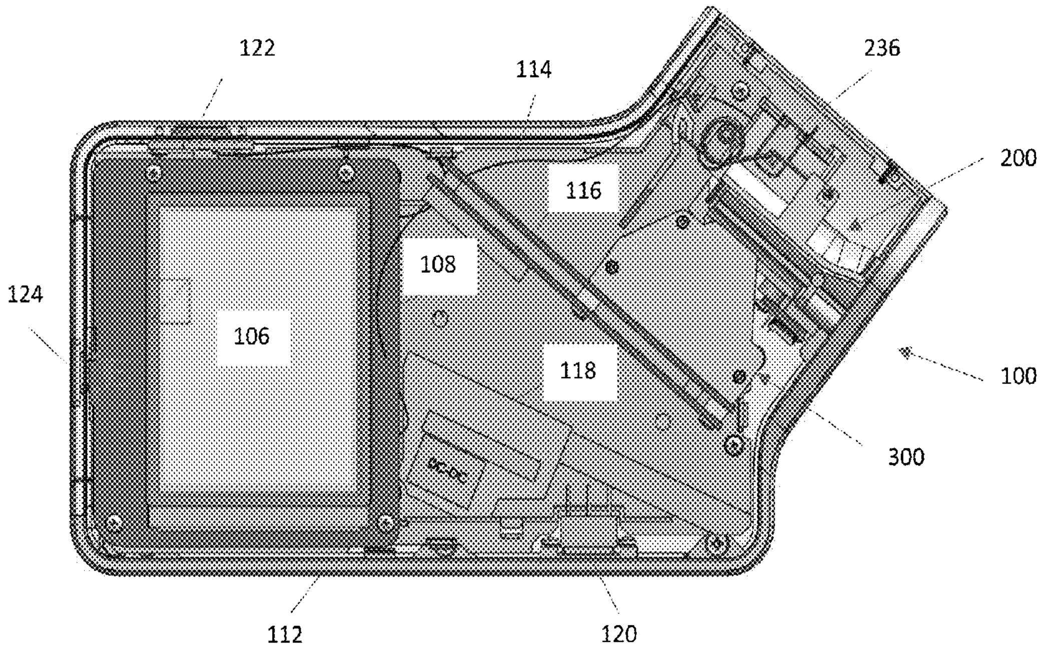
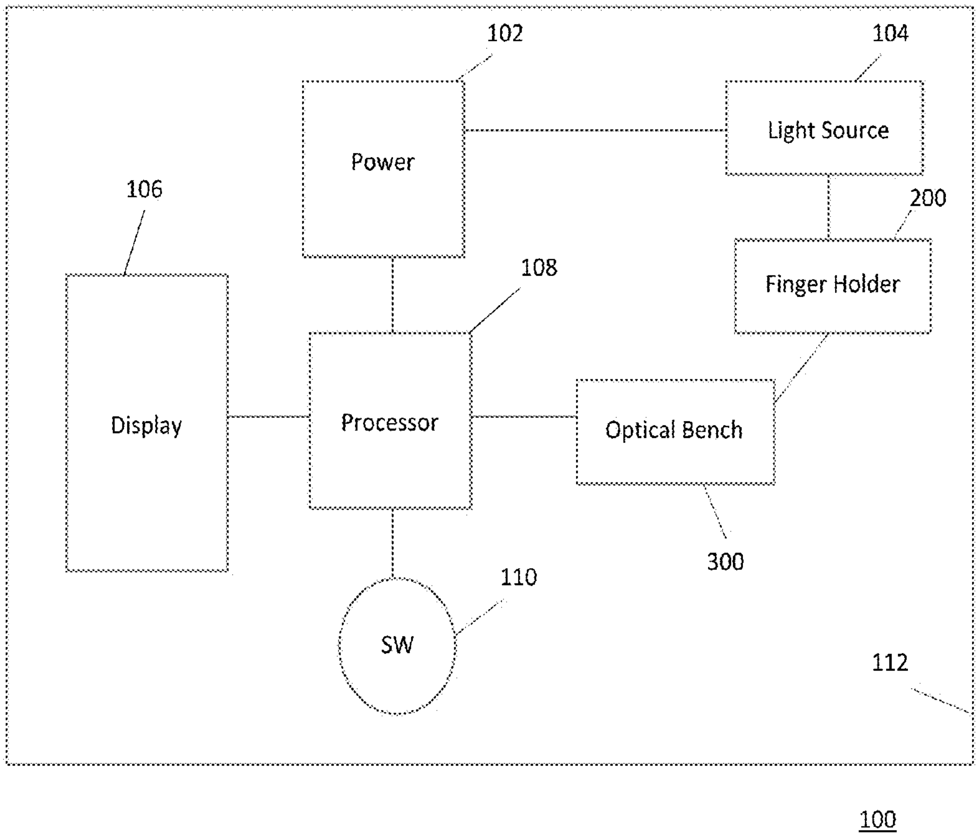
(57) **ABSTRACT**

A blood monitoring system employs a finger holder capable of receiving and stabilizing fingers of various sizes. A blood monitoring system employs a bandpass filter array capable of reducing optical crosstalk.




102
104
Power
Light Source
106
200
Finger Holder
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Display
Processor
Optical Bench
300
110
SW
112
100

FIG. 1

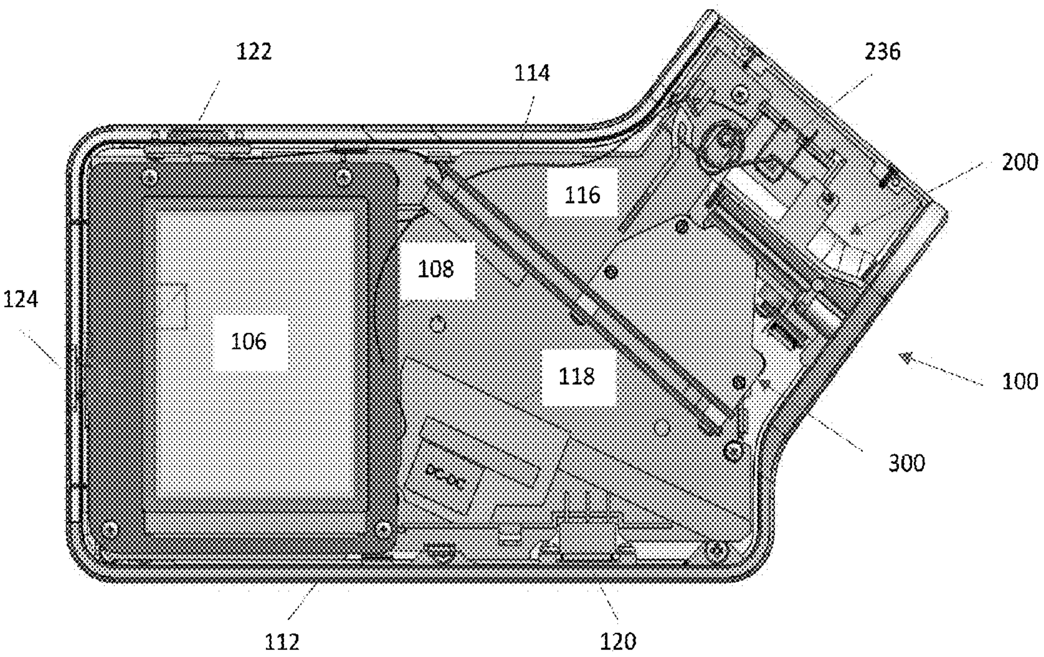

FIG. 2

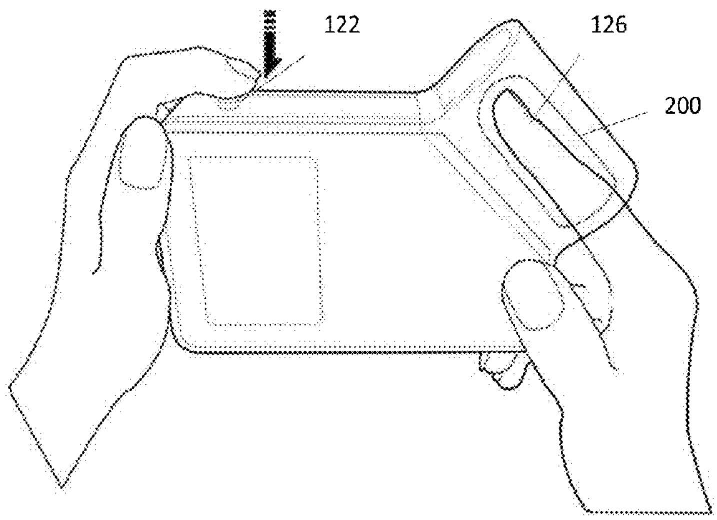

FIG. 3

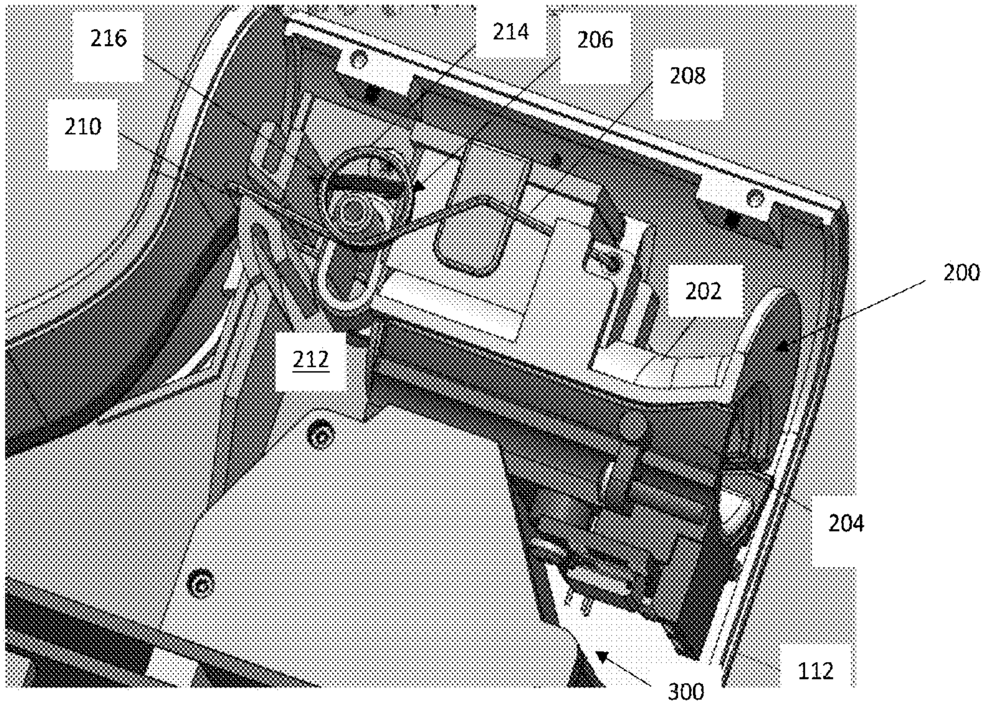
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FIG. 4

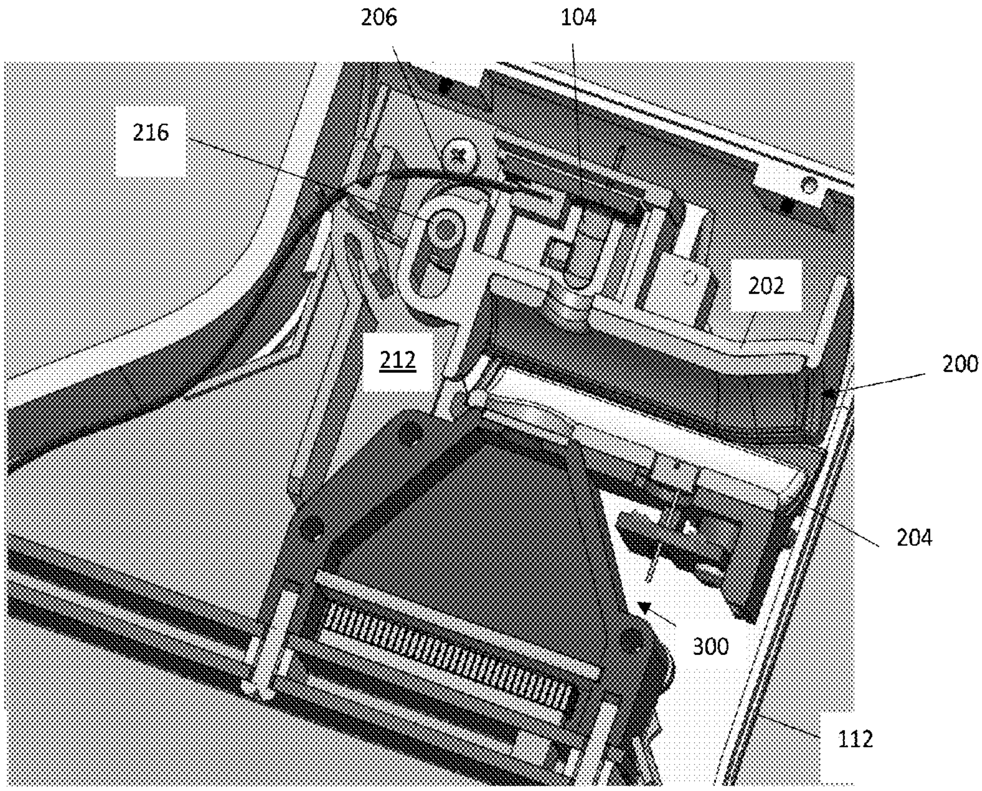
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FIG. 5

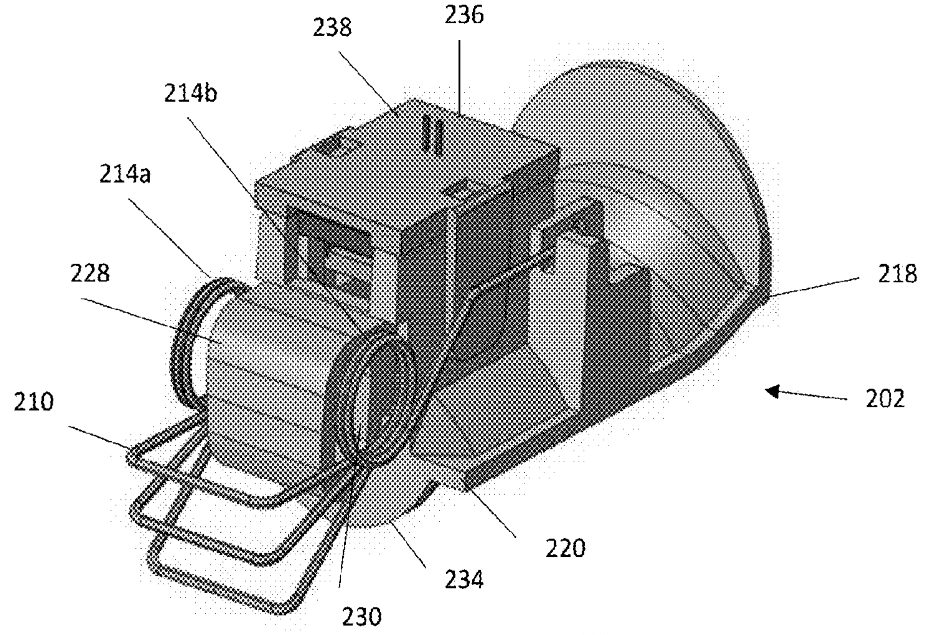
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FIG. 6

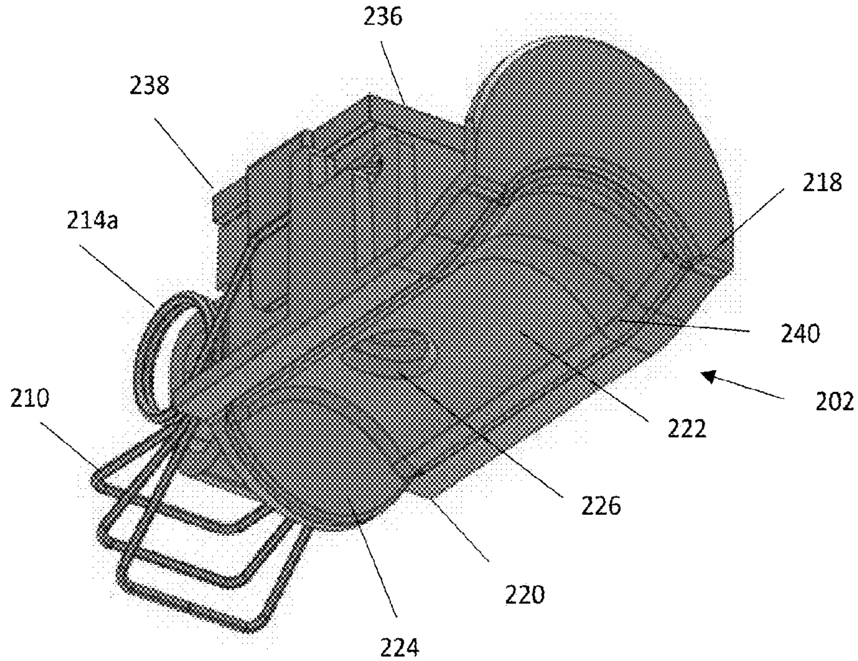
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FIG. 7

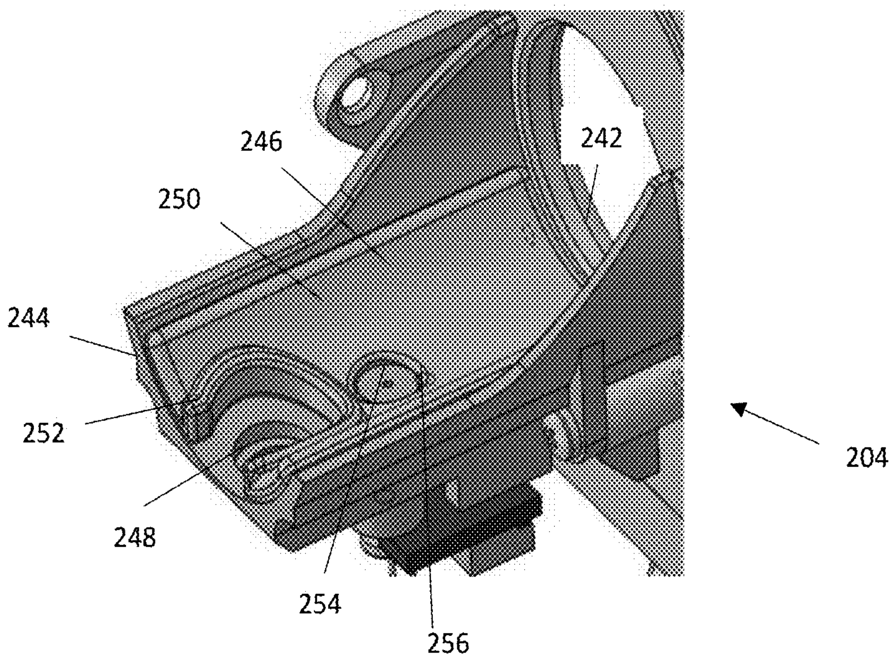

FIG. 8

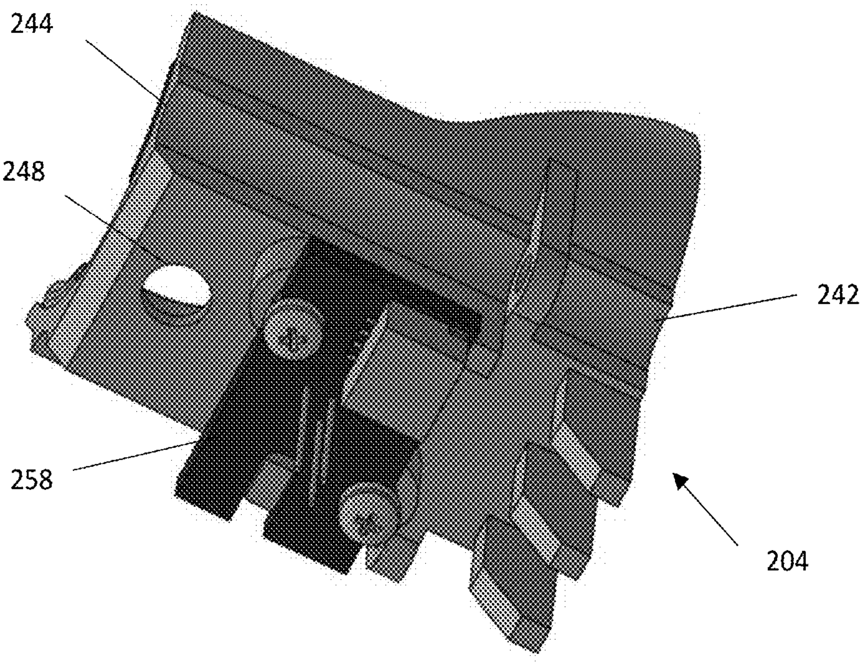

FIG. 9

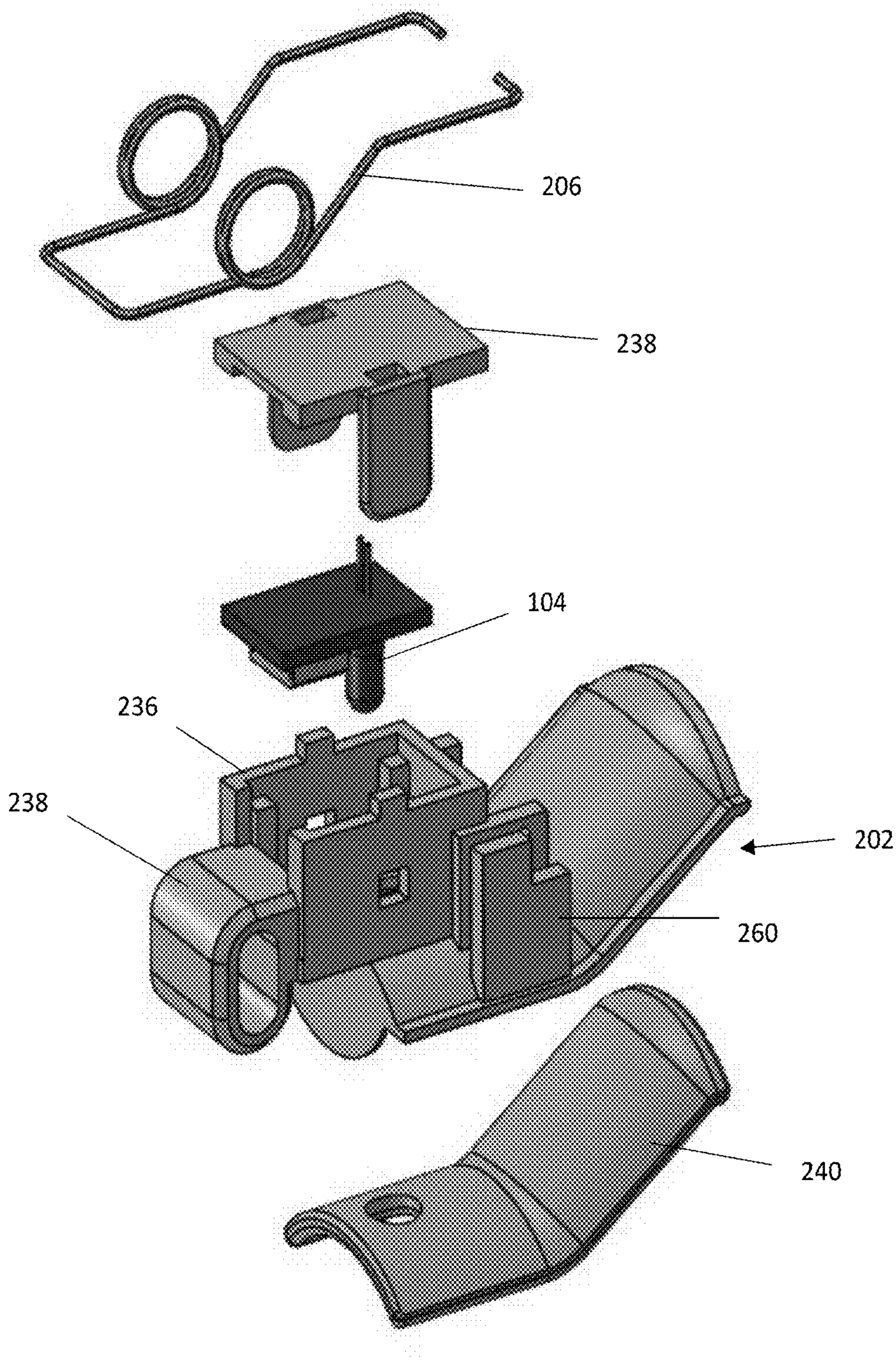

FIG. 10

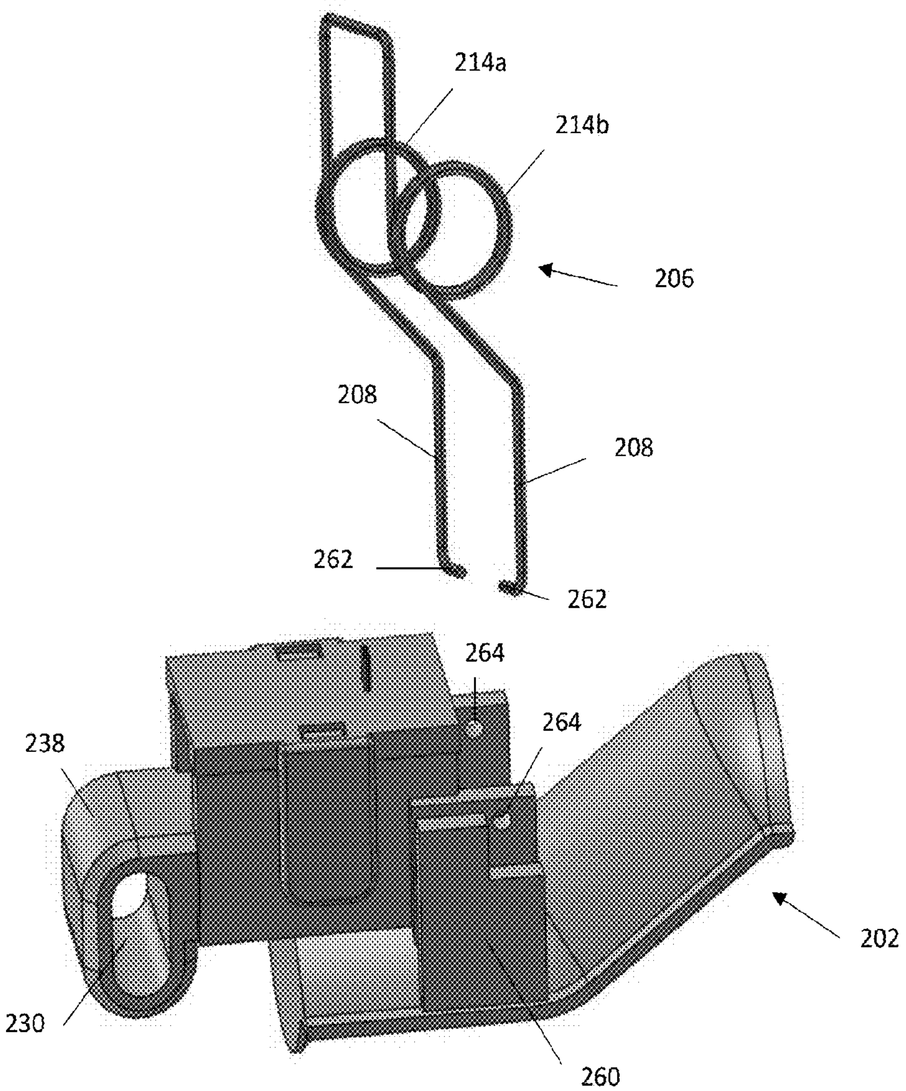
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FIG. 11

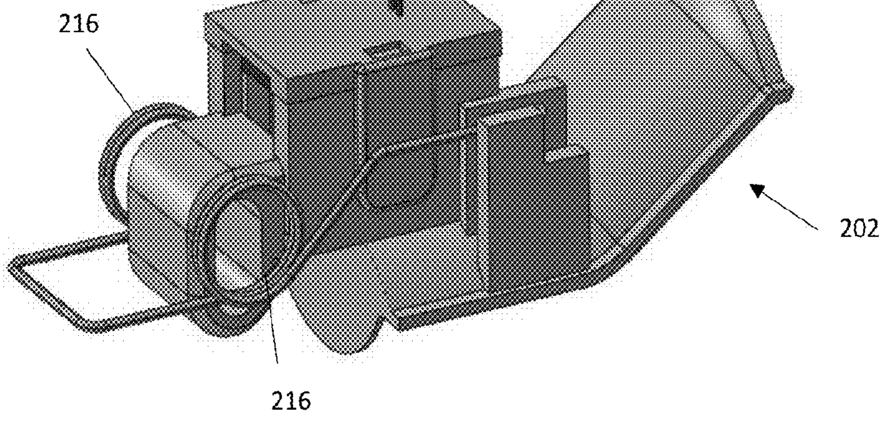
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FIG. 12

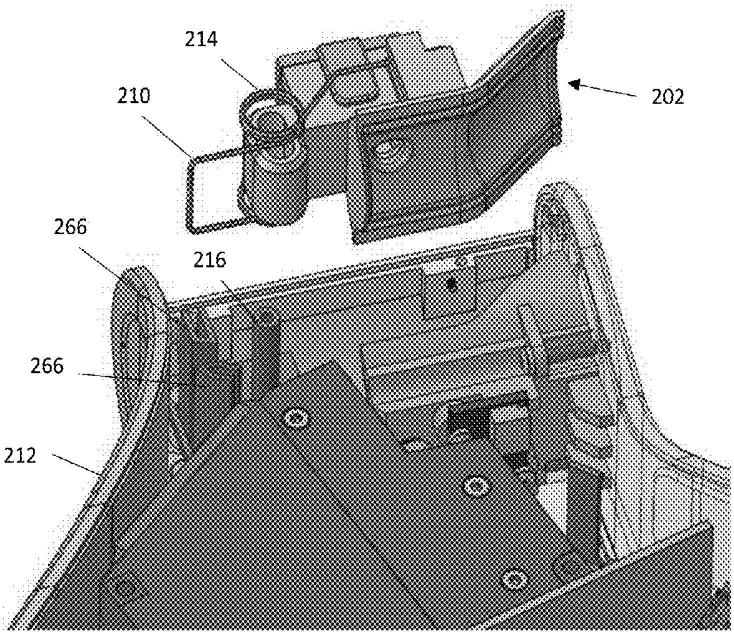
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FIG. 13

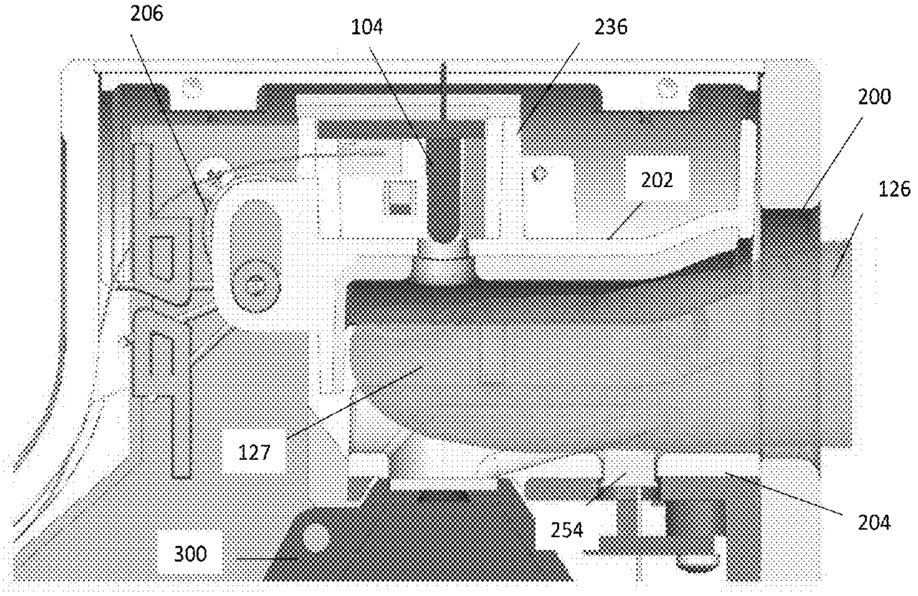
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FIG. 14

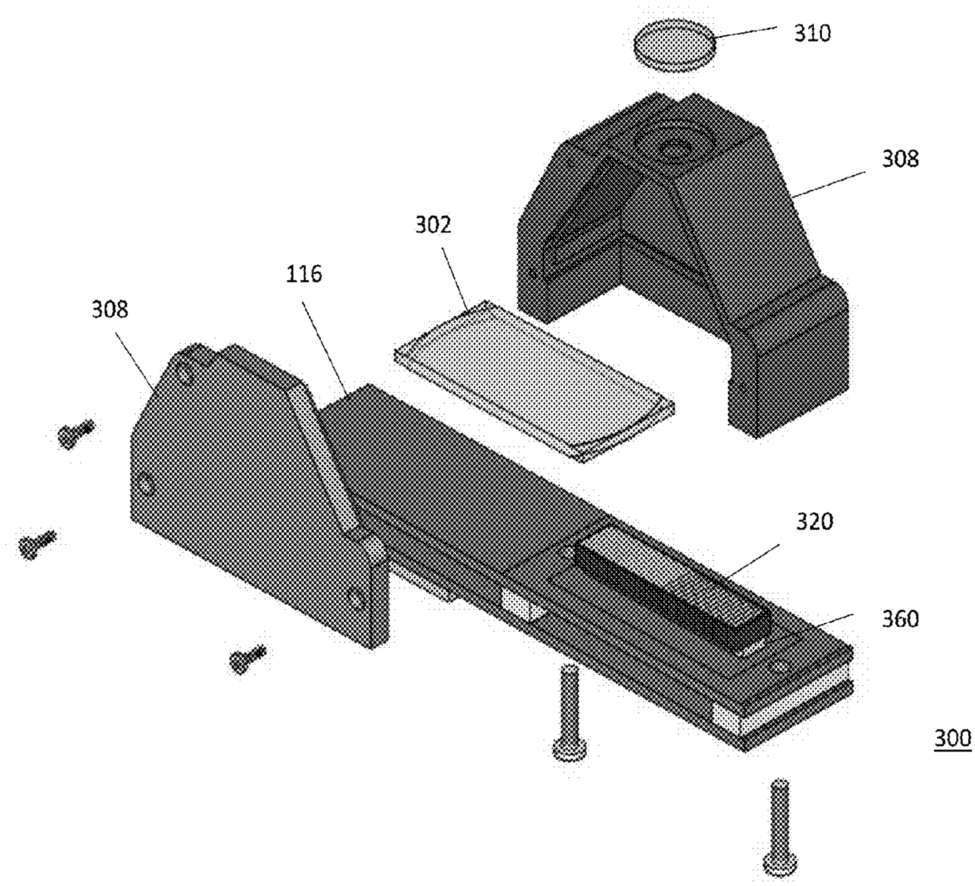


FIG. 15

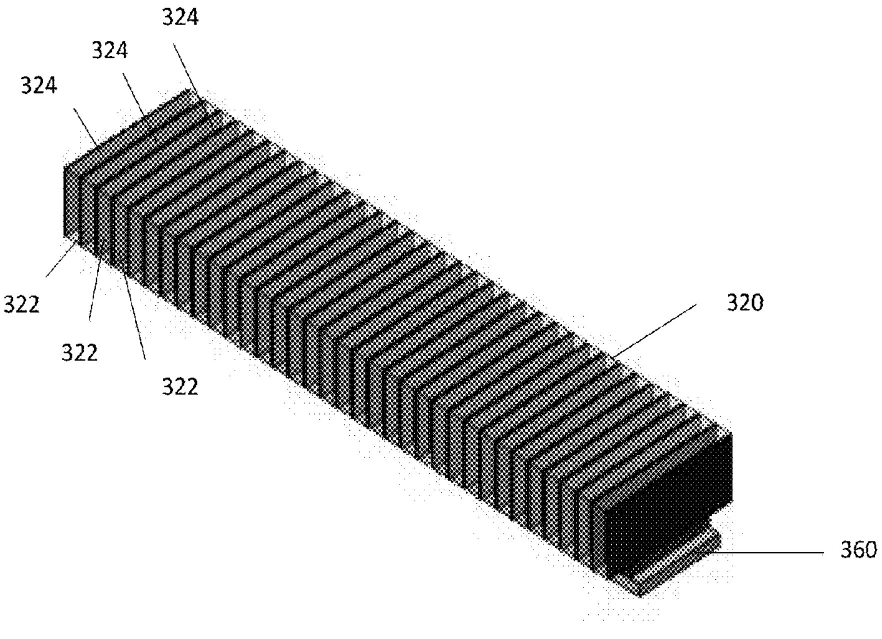


FIG. 16

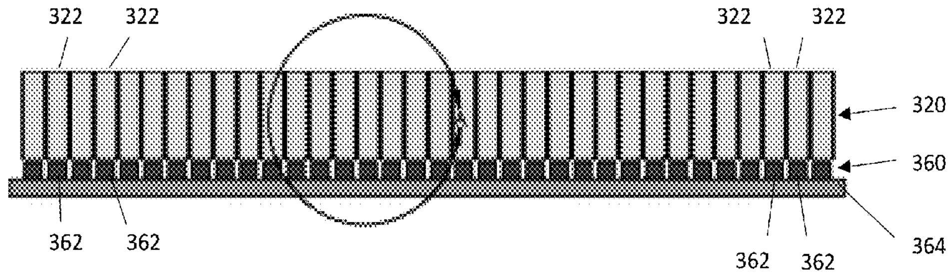


FIG. 17

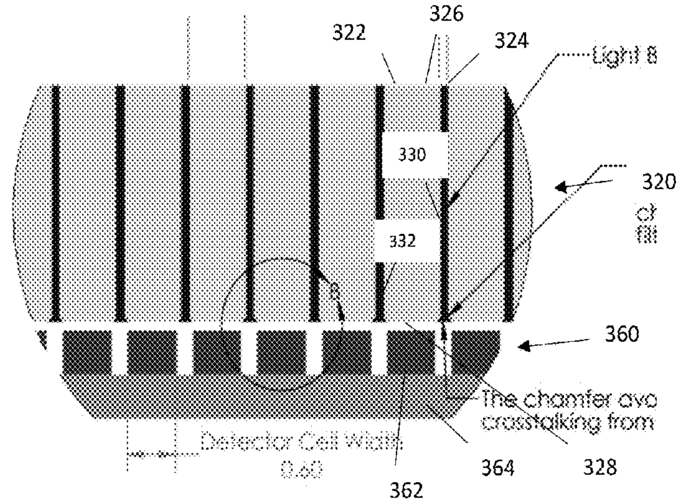


FIG. 18

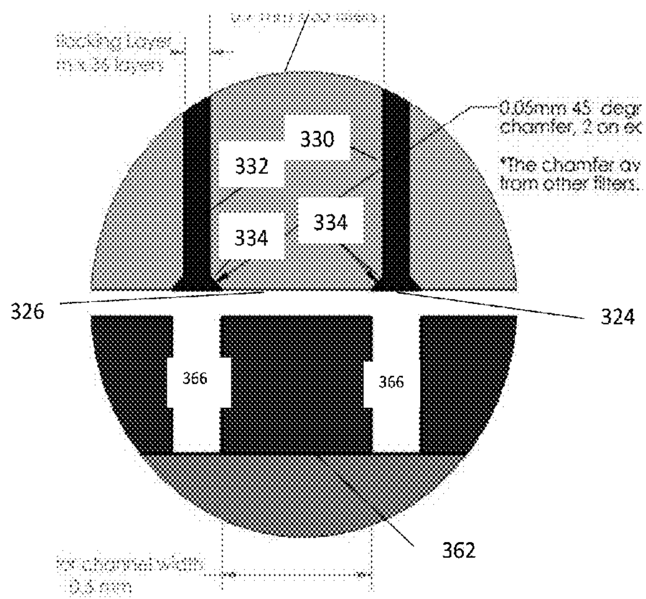
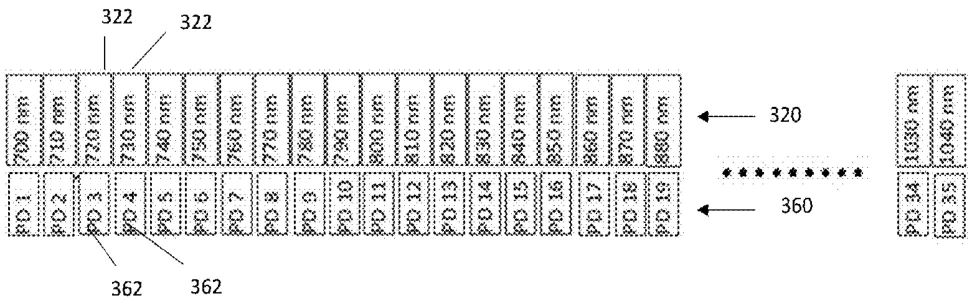


FIG. 19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860 nm
870 nm
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FIG. 20

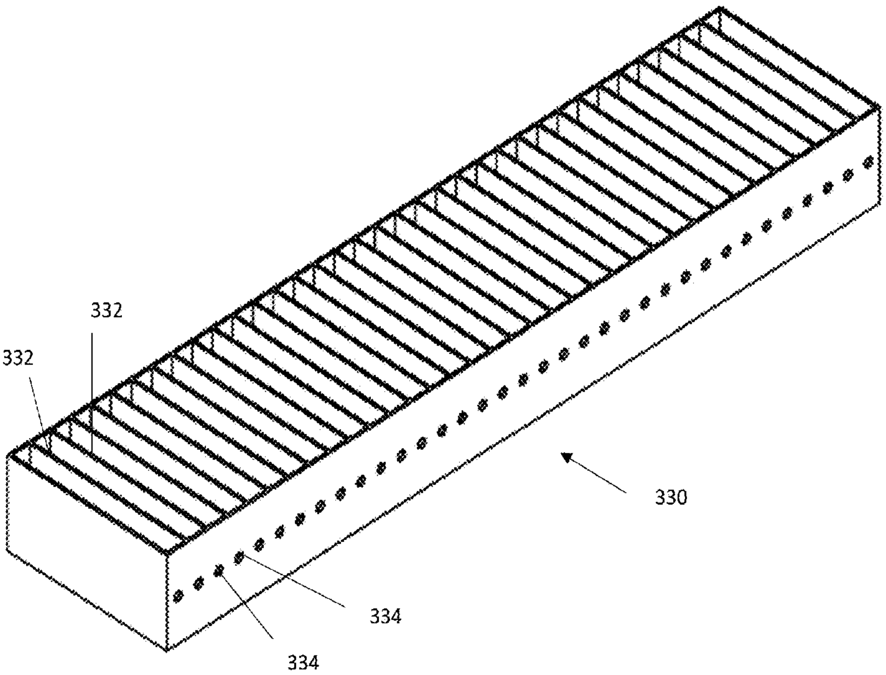
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FIG. 21

NON-INVASIVE GLUCOSE MONITORING SYSTEM

TECHNICAL FIELD

[0001] Embodiments of this disclosure relate generally to systems and methods for measuring constituents in a sample. In particular, various embodiments of a glucose monitoring system allowing noninvasive measurement of blood glucose are described.

BACKGROUND

[0002] Diabetes is a disease in which blood glucose levels are above normal. Most of the food people eat is turned into glucose or sugar for energy. The pancreas, an organ that lies near the stomach, makes insulin to help glucose enter body's cells. When people have diabetes, either the pancreas does not make enough insulin or the body cannot use their own insulin as well as it should. This causes sugar to build up in the blood.

[0003] Diabetes can cause serious health complications including heart disease, blindness, kidney failure, and lower-extremity amputations. The most serious problem caused by diabetes is heart disease. People with diabetes are more than twice likely to have heart disease or stroke. However, people with diabetes may not have the usual signs or symptoms of a heart attack. Therefore, the best way is to work with a healthcare team to keep the blood glucose, blood pressure, and cholesterol levels in the normal range. People with diabetes should work with healthcare providers which can monitors their diabetes control or help them learn to manage diabetes.

[0004] Conventionally, healthcare providers and patients use needle-prick devices to take blood from patients' fingers for testing blood glucose. The painful nature of drawing blood through skins discourages people from frequent testing of blood glucose, causing patients who have diabetes to not be as diligent as they should be for good blood glucose control. Accordingly, there exists a continuing need for glucose monitoring systems and methods that allow noninvasive measurement of blood glucose.

SUMMARY

[0005] Provided herein is a finger holder which can be used in a blood monitoring system. The finger holder comprises a first holder portion having a first end, a second end, and an inner surface extending from the first end to the second end, a second holder portion having a first end, a second end, and an inner surface extending from the first end to the second end, and torsion spring. The first ends of the first and second holder portions form an opening to admit a finger to be received between the inner surfaces of the first and second holder portions. The torsion spring comprises a first arm coupled to the first holder portion providing a force to urge the first holder portion to the second holder portion, a second arm anchored to a support member, and a spring coil retained by a retaining post secured to the support member allowing the first holder portion to rotate about the retaining post thereby increasing or decreasing a size of the opening admitting the finger.

[0006] In some embodiments, the first holder portion may further comprise a retaining structure at the second end. The retaining structure is provided with a through slot receiving the retaining post, allowing the first holder portion to translate relative to the second holder portion and the retaining post, thereby increasing or decreasing a space between the inner surfaces of the first and second holder portions.

[0007] In some embodiments, the spring coil may comprise a first coil section and a second coil section spaced apart and connected by the second arm. The first and second coil sections are disposed outside of the through slot of the retaining structure and retained by the retaining post.

[0008] In some embodiments, the first holder portion may further comprise an enclosure for enclosing a light source.

[0009] In some embodiments, the first holder may further comprise a stopper at the second end preventing the finger from extending beyond the finger holder.

[0010] In some embodiments, the second holder portion may further comprise a temperature sensor for detecting the temperature of the finger.

[0011] In some embodiments, the first holder portion may be provided with an aperture allowing light passing through to illuminate the finger, and the second holder portion may be provided with an aperture allowing light attenuated by the finger to exit through.

[0012] In some embodiments, the second holder portion may further comprise a ridge on the inner surface along the aperture of the second holder portion to position or stabilize a fingertip at the aperture of the second holder portion.

[0013] In some embodiments, the first and second holder portions may each comprise a finger pad constructed from a material comprising polyurethane or liquid silicone rubber.

[0014] Also provided herein is a bandpass filter array which can be used in a blood monitoring system. The bandpass filter array comprises a plurality of bandpass filters arranged side by side in an array and a plurality of light blocking layers in between neighboring bandpass filters. Each of the plurality of bandpass filters is configured to transmit light of a band of wavelengths, comprises a first end facing incident light, a second end exiting transmitted light, and a first side and a second side extending from the first end to the second end. The first and second sides of at least one of the plurality of bandpass filters are chamfered at the second end of the at least one of the plurality of bandpass filters. Each of the plurality of light blocking layers extends from the first end to the second end of the plurality of bandpass filters.

[0015] In some embodiments, each of the plurality of bandpass filters may be chamfered at the second end of each of the plurality of bandpass filters.

[0016] In some embodiments, the first and second sides of the at least one of the plurality of bandpass filters are chamfered with an angle ranging from 10 to 80 degrees, or are chamfered with an angle ranging from 30 to 60 degrees, or are chamfered with an angle of about 45 degrees.

[0017] In some embodiments, the first and second sides of each of the plurality of bandpass filters are chamfered with an angle ranging from 10 to 80 degrees, or are chamfered with an angle ranging from 30 to 60 degrees, or are chamfered with an angle of about 45 degrees.

[0018] In some embodiments, each of the plurality of bandpass filters has a transmission center wavelength different from a transmission center wavelength of a neighboring bandpass filter.

[0019] In some embodiments, the transmission center wavelengths of the plurality of bandpass filters are spread across a wavelength range from 700 to 1040 nanometers.

[0020] In some embodiments, the transmission center wavelengths of the plurality of bandpass filters are spread across the wavelength range in a successively increased or decreased order.

[0021] In some embodiments, the bandpass filter array may comprise 35 bandpass filters. Each of the 35 bandpass filters has a different transmission center wavelength. The transmission center wavelengths of the 35 bandpass filters may be spread from 700 to 1040 nanometers with a wavelength step of up to 10 nanometers.

[0022] In some embodiments, the bandpass filter array may further comprise a holder including a plurality of walls defining an array of cavities. The plurality of bandpass filters may be disposed in the array of cavities. In some embodiments, the holder may be constructed from a light blocking material.

[0023] Also provided herein is an optical apparatus comprising a collimation lens collimating incoming light, a bandpass filter array selectively transmitting the collimated light, and a detector array optically coupled to the bandpass filter array detecting light selectively transmitted by the bandpass filter array and generating output signals indicative of intensities of the light detected. The bandpass filter array comprises a plurality of bandpass filters and a plurality of light blocking layers in between neighboring bandpass filters, the detector array comprises a plurality of light-detection elements each corresponding to one of the plurality of bandpass filters. Each of the plurality of bandpass filters has a first end distal to the detector array, a second end proximal to the detector array, and a first side and a second side extending from the first end to the second end. The first and second sides of at least one of the plurality of bandpass filters are chamfered at the second end, thereby leading the light selectively transmitted by the at least one of the plurality of bandpass filters to the corresponding light-detection element.

[0024] Further provided is a blood monitoring system comprising a finger holder disclosed herein. The blood monitoring system comprises a light source producing light beams, a finger holder configured to hold a finger to be irradiated by the light beams, a detector array detecting light attenuated by the finger and generating output signals indicative of intensity of the light detected, and a processor determining a characteristic of a blood constituent in the finger based on the generated output signals. The finger holder comprises a first holder portion having a first end, a second end, and an inner surface extending from the first end to the second end, a second holder portion having a first end, a second end, and an inner surface extending from the first end to the second end, and a torsion spring. The first ends of the first and second holder portions form an opening to admit the finger to be received between the inner surfaces of the first and second holder portions. The torsion spring comprises a first arm coupled to the first holder portion providing a force to urge the first holder portion to the second holder portion, a second arm anchored to a support member, and a spring coil retained by a retaining post secured to the support member allowing the first holder portion to rotate about the retaining post thereby increasing or decreasing a size of the opening admitting the finger.

[0025] In some embodiments, the blood monitoring system may further comprise a casing enclosing the light source, the finger holder, the detector array, and the processor inside.

[0026] In some embodiments, the light source may be an incandescent light source.

[0027] In some embodiments, the processor may comprise a duo core processor.

[0028] Further provided is a blood monitoring system comprising a bandpass filter array disclosed herein. The blood monitoring system comprises a light source producing light beams having a range of wavelengths, a finger holder configured to hold a finger in operation, a collimation lens collimating light transmitted through the finger, a bandpass filter array selectively transmitting the collimated light, a detector array optically coupled to the bandpass filter array detecting light selectively transmitted by the bandpass filter array and generating output signals indicative of intensities of the light detected, and a processor determining a characteristic of a blood constituent in the finger based on the generated output signals. The bandpass filter array comprises a plurality of bandpass filters and a plurality of light blocking layers in between neighboring bandpass filters. The detector array comprises a plurality of light detection elements each corresponding to one of the plurality of bandpass filters. Each of the plurality of bandpass filters has a first end distal to the detector array, a second end proximal to the detector array, and a first side and a second side extending from the first end to the second end. The first and second sides of at least one of the plurality of bandpass filters are chamfered at the second end, thereby leading the light selectively transmitted by the at least one of the plurality of bandpass filters to the corresponding light-detection element.

[0029] In some embodiments, the light source may be an incandescent light source.

[0030] In some embodiments, the processor may comprise a duo core processor.

[0031] In some embodiments, the blood monitoring system may comprise a casing enclosing the light source, the finger holder, the collimation lens, the bandpass filter array, the detector array, and the processor inside.

[0032] This Summary is provided to introduce selected embodiments in a simplified form and is not intended to identify key features or essential characteristics of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter. The selected embodiments are presented merely to provide the reader with a brief summary of certain forms the invention might take and are not intended to limit the scope of the invention. Other aspects and embodiments of the disclosure are described in the section of Detailed Description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] These and various other features and advantages will become better understood upon reading of the following detailed description in conjunction with the accompanying drawings and the appended claims provided below, where:

[0034] FIG. **1** is a simplified block diagram illustrating an exemplary glucose monitoring system according to embodiments of the disclosure.

[0035] FIG. **2** is a cutaway view of an exemplary glucose monitoring system showing components according to embodiments of the disclosure.

[0036] FIG. **3** schematically shows the use of an exemplary glucose monitoring system according to embodiments of the disclosure.

[0037] FIG. **4** schematically shows an exemplary finger holder and an exemplary optical bench included in a glucose monitoring system according to embodiments of the disclosure.

[0038] FIG. **5** is a cutaway view of an exemplary finger holder and an exemplary optical bench included in a glucose monitoring system.

[0039] FIG. **6** is a top perspective view of an upper holder portion according to embodiments of the disclosure.

[0040] FIG. **7** is a bottom perspective view of an upper holder portion according to embodiments of the disclosure.

[0041] FIG. **8** is a top perspective view of a lower holder portion according to embodiments of the disclosure.

[0042] FIG. **9** is a bottom perspective view of a lower holder portion according to embodiments of the disclosure.

[0043] FIG. **10** is an exploded view of an upper holder portion and a torsion spring according to embodiments of the disclosure.

[0044] FIGS. **11** and **12** schematically show assembling of a torsion spring with an upper holder portion according to embodiments of the disclosure.

[0045] FIG. **13** schematically shows assembling of an upper holder portion-torsion spring in a glucose monitoring system according to embodiments of the disclosure.

[0046] FIG. **14** schematically shows a finger stabilized in a finger holder according to embodiments of the disclosure.

[0047] FIG. **15** is an exploded view of an exemplary optical bench according to embodiments of the disclosure.

[0048] FIG. **16** is a perspective view of an exemplary bandpass filter array coupled with a detector array according to embodiments of the disclosure.

[0049] FIG. **17** is a side cross-sectional view of the bandpass filter array coupled with a detector array shown in FIG. **16**.

[0050] FIG. **18** is an enlarged partial view of the bandpass filter array coupled with a detector array shown in FIG. **17**.

[0051] FIG. **19** is an enlarged partial view of a bandpass filter, light blocking layers, and a light-detection element according to embodiments of the disclosure.

[0052] FIG. **20** is a block diagram showing an exemplary bandpass filter array coupled to a detector array according to embodiments of the disclosure.

[0053] FIG. **21** is a perspective view of an exemplary bandpass filter holder according to embodiments of the disclosure.

DETAILED DESCRIPTION

[0054] Various embodiments of a blood monitoring system are described. It is to be understood that the disclosure is not limited to the particular embodiments described. An aspect described in conjunction with a particular embodiment is not necessarily limited to that embodiment and can be practiced in any other embodiments. For example, while various embodiments of the disclosure are described in connection with a system for monitoring blood glucose, it will be appreciated that the disclosed embodiments can be used for measuring other constituents in a sample fluid such as blood oxygen, cholesterol, and hemoglobin levels etc.

[0055] Various embodiments are described with reference to the figures. It should be noted that some figures are not necessarily drawn to scale. The figures are only intended to facilitate the description of specific embodiments, and are not intended as an exhaustive description or as a limitation on the scope of the disclosure. Further, in the figures and description, specific details may be set forth in order to provide a thorough understanding of the disclosure. It will be apparent to one of ordinary skill in the art that some of these specific details may not be employed to practice embodiments of the disclosure. In other instances, well known components may not be shown or described in detail in order to avoid unnecessarily obscuring embodiments of the disclosure.

[0056] All technical and scientific terms used herein have the meaning as commonly understood by one of ordinary skill in the art unless specifically defined otherwise. As used in the description and appended claims, the singular forms of "a," "an," and "the" include plural references unless the context clearly dictates otherwise. The term "or" refers to a nonexclusive "or" unless the context clearly dictates otherwise. The term "first" or "second" etc. may be used to distinguish one element from another. The use of the term "first" or "second" should not be construed as in any particular order unless the context clearly dictates otherwise. Further, the singular form of "first" and "second" include plural references unless the context clearly dictates otherwise.

[0057] Disclosed herein is a novel blood monitoring system that allows noninvasive, accurate measurement of blood constituents such as blood glucose through a human fingertip. The blood monitoring system includes a finger holder capable of holding or stabilizing human fingers of various sizes. The blood monitoring system may also include an optical bench that can significantly reduce or eliminate optical crosstalk and thus dramatically improve measurement accuracy and efficiency. The blood monitoring system can be self-contained, portable, and is user-friendly. Innovative software is provided to process or calculate measured data. The blood monitoring system enables automatic transmission of stored data to a data management system in a Wi-Fi, Bluetooth or other wireless or wired communication settings.

[0058] The disclosed blood monitoring system employs the principle of pulsatile heartbeat spectroscope to extract information from the blood. Pulsatile heartbeat spectroscope is known in the art. Briefly and in general, when light is transmitted through a biological sample such as a human finger, light is absorbed and scattered, or attenuated, by various components of the finger including skin, muscle, bone, fat, interstitial fluid and blood. Light attenuation by a human finger exhibits a cyclic pattern that corresponds to the heartbeat. By way of example, the magnitude of measured photocurrent indicative of the intensity of light transmitted through the human finger exhibits a plot form of pulse waves due to the heartbeat of the user. The plot form includes a plurality of maximums or peaks and a plurality of minimums or valleys. The peak readings of the plot form correspond to when there is a minimal amount of blood in the capillaries of the finger, and the valley readings correspond to when there is a maximal amount of blood in the capillaries of the finger. By using the optical information provided by the peaks and valleys of the cyclic plot, the optical attenuation by major finger constituents that are not in the capillaries such as skin, fat, bones, muscle and interstitial fluids can be excluded, and light that is attenuated by the blood can be measured. Light attenuation caused by blood can be used to determine a glucose level in the blood. For example, by calculating the blood absorption value and comparing the calculated value to predetermined values corresponding to different glucose levels, a blood glucose level of the user can be determined.

[0059] FIG. **1** is a simplified block diagram illustrating some components of an exemplary blood glucose monitoring system **100** according to embodiments of the disclosure. As shown, the blood glucose monitoring system **100** may include a power source **102**, a light source **104**, a finger holder **200**, an optical bench **300**, a display **106**, a processor **108**, and a software program **110**, operably and communicably interconnected as shown. The power source **102** provides power to the light source **104** which produces light beams to irradiate a finger held or stabilized in a finger holder **200**. The optical bench **300** collects, filters, and detects light attenuated by the finger and generates output signals indicative of the intensity of light detected. The processor **108** executes the software program **110** to calculate a change of light attenuation by the blood in the finger. The change of light attenuation can be used to determine the glucose level in the blood. For example, by comparing the calculated light absorption value to predetermined values corresponding to different glucose levels stored in a memory, a glucose level of the user can be determined. The display **106** can present measurement parameters and/or calculation results. A casing **112** may enclose the power source **102**, the light source **104**, the finger holder **200**, the optical bench **300**, the display **106**, the processor **108**, and other electrical, mechanical, and optical components inside, rendering the blood glucose monitoring system **100** portable or self-contained.

[0060] The power source **102** may include a battery such as a thin profile lithium-ion battery. In some embodiments of the disclosure, the power source **102** may be a rechargeable power source. Suitable power source **102** includes but is not limited to MIKROE-1120 and MLP674361 batteries manufactured by Mikro Elektronika of Belgrade, Serbia.

[0061] The light source **104** may be an incandescent light source emitting an energy spectrum of a wide range of wavelengths e.g. from 700 to 1600 nanometers. Alternatively, the light source **104** may be a light-emitting diode (LED) emitting an energy spectrum of a narrower range of wavelengths. In some embodiments, the light source **104** may include a plurality of LEDs each emitting an energy spectrum of a specified range of wavelengths. By way of nonlimiting example, an incandescent lamp rated at 5.0 volts and 60 mA emitting a spectrum of wavelengths between 700 to 1600 nanometers can be used. Suitable light source **104** includes but is not limited to Model No. 7683 incandescent lamp manufactured by JKL Components Corporation of Pacoima, Calif., which has an average life expectancy of 1000,000 hours.

[0062] The processor **108** can be any suitable microprocessor which incorporates the functions of a computer's central processing unit (CPU) on an integrated circuit. The processor **108** may be a single CPU or dual CPU or dual core microprocessor. By way of example, the processor **108** can be Model No. STM32F407/417 microprocessor manufactured by ST Microelectronics Inc. of Santa Clara, Calif. The STM32F407/417 microprocessor provides high level of integration and performance and includes embedded memories and rich peripheral set inside packages as small as 10×10 mm. The STM32F407/417 microprocessor provides the performance of the Cortex™-M4 core (with floating point unit) running at 168 MHz. It will be appreciated by one of ordinary skill in the art that other suitable microprocessors can also be used.

[0063] FIG. **2** is a cutaway view of an exemplary glucose monitoring system **100** showing arrangements of some components according to embodiments of the disclosure. The finger holder is indicated at **200**. The light source **104** (shown in FIG. **1** but not in FIG. **2**) is enclosed in a light source housing **236** on the finger holder **200**. The optical bench is indicated at **300**. The display is indicated at **106**. The processor or CPU board including a memory, a processor, and other electrical circuitries is indicated at **108**. While not visible or shown in FIG. **2**, the power source can be e.g. disposed below the CPU board **108**, supplying power to the light source **104** via a flexible cable **114** and to other components via buses or flexible cables. Reference **116** indicates an operational amplifier board coupled to the optical bench **300**. Reference **118** indicates an analog-to-digital converter board. A power switch is indicated at **120**, a glucose measurement button is indicated at **122**, and a data transmission port such as a USB port is indicated at **124**. The casing **112** encloses the components of the monitoring system inside. FIG. **3** schematically shows that a user is taking blood glucose measurement by inserting a finger **126** in the finger holder **200** and pressing the measurement button **122**.

Finger Holder

[0064] Referring now to FIGS. **4-14**, embodiments of a finger holder will now be described. FIGS. **4** and **5** schematically shows an exemplary finger holder **200** included in a blood glucose monitoring system according to embodiments of the disclosure. As shown, the exemplary finger holder **200** in general includes an upper (first) holder portion **202**, a lower (second) holder portion **204**, and a torsion spring **206** coupling the upper and lower holder portions **202**, **204**. The torsion spring **206** may include a first arm **208** urging the upper holder portion **202** to the lower holder portion **204**, a second arm **210** anchored to a support member **212**, and a spring coil **214**. The spring coil **214** of the torsion spring **206** may be retained by a retaining post **216** secured to the support member **212**, allowing the upper holder portion **202** to rotate about the retaining post **216**. In embodiments of the disclosure, the finger holder **200** may be enclosed inside the casing **112**. The lower holder portion **204** may be fixedly attached to the casing **112**, whereas the upper holder portion **202** may be movable relative to the lower holder portion **204** to accommodate fingers of various sizes.

[0065] FIG. **6** is a top perspective view, FIG. **7** a bottom perspective view of an exemplary upper (first) holder portion **202** according to embodiments of the disclosure. As shown, the upper holder portion **202** include a first end **218**, a second end **220**, and an inner surface **222** extending from the first end **218** to the second end **220**. The contour of first end **218** of the upper holder portion **202** and the first end **242** of the lower holder portion **204**, to be described below, forms an opening to admit a finger. The inner surface **222** of the upper holder portion **202** may be contoured to conform to a portion of the finger. At the second end **220** of the upper holder portion **202**, a stopper **224** may be provided to prevent the fingertip from extending beyond the finger holder **200**. An aperture **226** is provided in the upper holder portion **202** to allow light emitted from the light source passing through to irradiate the finger.

[0066] The upper holder portion **202** may include a spring-retaining or retaining structure **228** at the second end **220**. The retaining structure **228** may be provided with a through slot or opening **230** receiving the retaining post **216** (FIGS. **4** and **5**). The through slot **230** may have an elongate profile, allowing the upper holder portion **202** to translate or move up and down relative to the lower holder portion **204**, thereby increasing or decreasing the space between the inner surfaces of the upper and lower holder portions **202**, **204** to accommodate fingers of different sizes. The spring coil **214** of the torsion spring **206** may include a first coil section **214***a* and a second coil section **214***b* spaced apart and connected by the second arm **210**, which may be anchored to an anchor support. The first and second spring coil sections **214***a*, **214***b* may be disposed at either side of the retaining structure **228** and retained by the retaining post **216** (FIGS. **4** and **5**).

[0067] Still referring to FIGS. **6** and **7**, the upper holder portion **202** may also include an enclosure **236** enclosing a light source **104** (FIG. **5**). The enclosure **236** may include an aperture that aligns with the aperture **226** in the upper holder portion **202** to provide an optical path for light beams. The enclosure **236** may include a cover **238** onto which the light source **104** and an electrical circuitry board for the light source may be mounted.

[0068] Referring to FIG. **7**, the upper holder portion **202** may include a finger pad **240**. The finger pad **240** may be made of a material that can properly stabilize or encapsulate the finger or provide comfort to the patient. The finger pad **240** may also block or minimize stray light that would otherwise affect measurement. Suitable materials for the finger pad **240** include silicone, rubber, foam, or the like. By way of nonlimiting example, thermoplastic materials such as polyurethane (Gemothane®), liquid silicone rubber may be used for constructing the finger pad **240**. The finger pad **240** may be attached to the inner surface of the upper holder portion **202** by e.g. adhesives or other suitable means. Alternatively, the finger pad **240** may constitute a part of the inner surface **222** of the upper holder portion **202**.

[0069] FIG. **8** is a top perspective view, FIG. **9** a bottom perspective view of an exemplary lower (second) holder portion **204** according to embodiments of the disclosure. As shown, the lower holder portion **204** includes a first end **242**, a second end **244**, and an inner surface **246** extending from the first end **242** to the second end **244**. The first end **242** of the lower holder portion **204** and the first end **218** of the upper holder portion **202**, described above, forms an opening for admitting a finger. The inner surface **246** of the lower holder portion **204** may be contoured to conform to a portion of the finger. An aperture **248** is provided in the lower holder portion **204** to allow light attenuated by or transmitted through the finger to exit to an optical bench, to be described below.

[0070] The lower holder portion **204** may include a finger pad **250**. The finger pad **250** may be made of a material that can properly stabilize or encapsulate the finger or increase patient's comfort. The finger pad **250** may also block or minimize stray light that would affect measurement. Suitable materials for the finger pad **250** include silicone, rubber, foam, or the like. By way of nonlimiting example, thermoplastic materials such as polyurethane (Gemothane®), liquid silicone rubber may be used for constructing the finger pad. The finger pad **250** may be attached to the inner surface of the lower holder portion **204** by e.g. adhesives or other suitable means. Alternatively, the finger pad **250** may constitute a part of the inner surface of the lower holder portion **204**. In some embodiments, a ridge **252** along the aperture **248** of the lower holder portion **204** may be provided to help position or stabilize a fingertip at the aperture **248**. Alternatively, in some embodiments, an indentation generally conforming to the fingertip may be provided near the aperture to help position or stabilize the fingertip.

[0071] Still referring to FIGS. **8** and **9**, in some embodiments, the lower holder portion **204** may include a temperature sensor **254** for detecting the temperature of the patient's finger. The temperature sensor **254** may be disposed in an aperture **256** in the lower holder portion **204**. An electrical circuitry board **258** for the temperature sensor **254** may be attached to the bottom of the lower holder portion **204** by e.g. screws, pins or the like. The temperature sensor **254** may be integrated circuit sensors or electrical temperature sensors. By way of nonlimiting example, the temperature sensor **254** may be an infrared temperature sensor.

[0072] The lower holder portion **204** may be fixedly attached to a support body such as the casing **112** (FIGS. **4** and **5**) with screws or other mounting structures. In use, the patient's finger can be held by the lower holder portion **204**. The upper holder portion **204** can pivot about the retaining post **216** to increase or decrease the opening formed by the first ends **218**, **242** of the upper and lower holder portions **202**, **204**, or move up or down to increase or decrease the space between the upper and lower holder portions **202**, **204**. Advantageously, an adjustable finger holder **200** disclosed herein can accommodate patient's fingers of different sizes, which can be received and gripped by the upper and lower holder portions **202**, **204** with comfort. The elongate inner surfaces **222**, **246** of the first and second holder portions **202**, **204** can uniformly distribution the urging pressure applied by the torsion spring **206**, improving measurement accuracy. Fingers of various sizes can be conformably stabilized in the finger holder **200** but not squeezed or clamped too tightly. Clamping the finger too tightly would cause patient discomfort and measurement inaccuracy.

[0073] FIG. **10** is an exploded view showing individual parts of a torsion spring **206**, a cover **238** for a light source enclosure **236**, a light source **104**, an upper holder portion **202** including a spring retaining structure **238**, a light source enclosure **236**, spring retaining walls **260**, and a finger pad **240**. FIG. **11** and FIG. **12** show assembling of the torsion spring **206** to the upper holder portion **202**. FIG. **13** shows assembling of the upper holder portion **202**-torsion spring **206** in a blood glucose monitoring system.

[0074] As shown in FIGS. **11** and **12**, the first arm **208** of the torsion spring **206** may include two hooks or ends **262**, which can be inserted into the holes **264** in the retaining walls **260** on either side of the upper holder portion **202**. The torsion spring **206** can be then swung down to align the spring coils **214***a*, **214***b* with the through slot **230** of the spring retaining structure **238**. The retaining walls **260** may constrain the first arm **208**, keeping the ends **262** of the first arm **208** in the holes **264** when the upper holder portion **202** pivots or moves. The upper holder portion **202** with the torsion spring **206** can be then assembled in the monitoring system as shown in FIG. **13**, with the spring coils **214** being retained by the retaining post **216**, which is fixed on the support member **212**, and the second arm **210** being anchored to the anchors **266**, which are fixed on the support member **212**. The support member **212** may be part of the casing **112**, or a separate support frame attached to the casing **112**.

[0075] FIG. **14** schematically shows a finger **126** inserted into the finger holder **200**, with the fingertip **127** being aligned with the apertures in the light source enclosure **236** and in the upper and lower holder portions **202**, **204**. The torsion spring **206** applies a force on the upper holder portion **202**, causing the finger to be gripped or stabilized in the finger holder **200** during measurement. Light beams from the light source **104** passes through the aperture in the upper holder portion **202**, irradiating the fingertip **127** Light attenuated by the fingertip exits the aperture in the lower holder portion **204** and detected by a detector array in the optical bench **300**, to be described in greater detail below. The temperature sensor **254** measures the patient's temperature through the patient finger **126**.

Optical Bench

[0076] Referring to FIGS. **15-21**, embodiments of an optical bench or apparatus **300** will now be described. FIG. **15** is an exploded view of an exemplary optical bench **300** according to embodiments of the disclosure. As shown, the optical bench **300** may include a collimation lens **302**, a bandpass filter array **320**, a detector array **360**, and a housing **308** enclosing the collimation lens **302**, the bandpass filter array **320**, the detector array **360**, and optionally a portion of an operational amplifier board **116**. The housing **308** may include an optical window **310** allowing light to pass through. An assembled optical bench **300** is shown in FIGS. **2** and **4**. A cutaway view of an optical bench **300** is shown in FIG. **5**.

[0077] Referring to FIGS. **15-21**, the collimation lens **302** collimates light attenuated e.g. by a finger, which may diffuse in various directions. Any suitable collimation lens may be used. In an exemplary embodiment, a Fresnel lens may be used as the collimation lens **302**. A Fresnel lens, which may be made thin or compact, includes a series of concentric grooves replacing the curved surface of a conventional optical lens. Alternatively, a singlet, doublet or aspheric lens can be used as collimation lens **302**.

[0078] The bandpass filter array **320** selectively transmits collimated light from the collimation lens **302**. As shown in greater detail in FIGS. **16-19**, the bandpass filter array **320** may include a plurality of bandpass filters **322** arranged side by side in an array. Between neighboring bandpass filters **322**, light blocking layers **324** are disposed to suppress light crosstalk among neighboring bandpass filters **322**. The light blocking layers **324** may be made of light absorbing materials such as polycarbonate or other suitable polymer materials. Alternatively, the light blocking layers **324** may be made of light reflective materials such as Mylar or the like. The light blocking layers **324** may prevent light in a bandpass filter from escaping to neighboring bandpass filters, leading light transmitted by a particular bandpass filter **322** to a corresponding light detection element **362** directly underneath the bandpass filter.

[0079] The detector array **360** detects light transmitted through the bandpass filter array **320**. The detector array **360** may include a plurality of detection elements **362**. Each of the detection elements **362** may include a photosensitive element configured to convert light into electrical signals and a switching element for access to the electrical charges by readout electronics. The photosensitive element may be a photodiode, a photoconductor, a photogate, or a phototransistor etc. The switching element may be a thin film transistor (TFT) or other switching elements such as organic transistors, charge coupled devices (CCDs), CMOS, metal oxide transistors, or transistors made of other semiconductor materials, and/or switching diodes. The TFTs may be amorphous silicon (a-Si), metal oxide or polycrystalline silicon TFTs. The photosensitive elements and switching elements may be formed on a substrate **364** by any methods known in the art, and thus their detail description is omitted here in order to focus on description of embodiments of this disclosure. The detector array **360** may be optically coupled to the bandpass filter array **320** by optically transparent adhesive or other suitable means.

[0080] The plurality detection elements **362** of the detector array **360** and the plurality of filters **322** of the bandpass filter array **320** may be arranged such that each detection element **362** corresponds to one of the plurality of bandpass filters **322**. Each of the detection elements **362** detects light transmitted by one of the bandpass filters **322** and generates current signals that is proportional to the power of light received by the detection element **362**. The current signal generated by the detection element **362** may be converted to another form of signal such as an analog voltage signal or a digital signal by an operational analog-digital converter.

[0081] Referring to FIG. **20**, each of the plurality of bandpass filters **322** may be configured to transmit a selected band of wavelengths. In the following description and appended claims, the term "transmission center wavelength" may be used to refer to a center wavelength of an optical spectrum that a bandpass filter transmits. As shown in FIG. **20**, each of the plurality of bandpass filters **322** may have a unique transmission center wavelength. For example, a bandpass filter **322** may have a transmission center wavelength different from a neighboring bandpass filter.

[0082] The bandpass filters **322** may be arranged such that the transmission center wavelengths of the plurality of bandpass filters are spread across a wavelength range. By way of example, the transmission center wavelengths of the plurality of bandpass filters may be spread across a wavelength range from 700 to 1040 nanometer, as shown in FIG. **20**. The transmission center wavelengths of the plurality of bandpass filters **322** may be spread across a wavelength range in a successively increased or decreased order. In some embodiments, the transmission center wavelengths of the plurality of bandpass filters may be spread across wavelength range by a constant wavelength step such as 10, 20, 30, 40, or 50 nanometers and so on, or by an integer multiple of a wavelength step.

[0083] In the nonlimiting exemplary embodiment shown in FIG. **20**, the bandpass filter array **320** includes 35 bandpass filters **322** each having a unique transmission center wavelength. The transmission center wavelengths of the 35 bandpass filters are spread from 700 to 1040 nanometers with a wavelength step of up to 10 nanometers. It should be noted that FIG. **20** is provided for illustration purpose and the bandpass filter array **320** according to embodiments of the disclosure may include more or less than 35 filters. Further, the bandpass filters **322** may be arranged in any desirable orders and thus their transmission center wavelengths are not necessarily in a successively increased or decreased order.

[0084] Still referring to FIG. **20**, each of the bandpass filters **322** corresponds to one of the light detection elements

362 located below each bandpass filter 322. By way of example, light detection element PD1 receives light transmitted from the bandpass filter having a transmission center wavelength of 700 nm. Light detection element PD4 receives light from the bandpass filter having a transmission center wavelength of 730 nm. The design and construction of the disclosed bandpass filter array 320 can prevent or suppress light transmitted from e.g. the bandpass filter having a transmission center wavelength of 780 nm from propagating to the adjacent light detection elements PD8 or PD10, thereby preventing or reducing potential optical crosstalk.

[0085] Referring to FIGS. 18 and 19, each of the plurality of bandpass filters 322 may include a first end 326 facing incident light, a second end 328 exiting light transmitted through the filter, a first side 330 and a second side 332 extending from the first end 326 to the second end 323. According to embodiments of the disclosure, the first and second sides 330, 332 of at least some of the plurality of bandpass filters 322 are chamfered at the second end 328 of the at least some of the plurality of bandpass filters 322. In some embodiments, the first and second sides 330, 332 of each of the plurality of bandpass filters 322 are chamfered at the second end 328 of each of the plurality of bandpass filters 322. Advantageously, the chamfered configuration at the bottom of a bandpass filter, along with the light blocking layers, can prevent light from the bandpass filter from traveling across neighboring light detection elements, thereby further suppressing or reducing any potential optical crosstalk.

[0086] In the following description and appended claims, the term "chamfer angle" may be used to refer to an angle between the first or second side surface 330, 332 of a bandpass filter 322 and the beveled surface 334 at the bottom or second end 328 of the filter 322. According to embodiments of the disclosure, the chamfer angle of a bandpass filter 322 may be any angle in the range from 10 to 80 degrees. In some embodiments, the chamfer angle may be any angle in the range from 30 to 60 degrees. In an exemplary example, the chamfer angle may be about 45 degrees. In another exemplary example, the chamfer angle of a bandpass filter may be about 60 degrees. As illustrated in FIG. 19, the light blocking layer 324 on the chamfered portion of a bandpass filter 322 will block light in a direction that would propagate into neighboring light detection elements.

[0087] In embodiments of the disclosure, the light blocking layer 324 at the bandpass filters 322 may extend at least partially or all the way down to the space 366 between light detection elements 362. In alternative embodiments, the detector array 360 may include a plurality of light blockers (not shown) each may be disposed in the space 366 between two neighboring detection elements 362. The light blockers may be made of light absorbing materials that absorb light and thus help prevent light from entering into neighboring detection elements.

[0088] FIG. 21 is a perspective view of an exemplary filter holder 330 for holding bandpass filters 322 according to embodiments of the disclosure. As shown, the holder 330 may include a plurality of walls 332 defining an array of cavities for holding a plurality of bandpass filters 322 disposed therein. A plurality of apertures 334 may be provided in the side walls for receiving e.g. adhesives to secure the bandpass filters 322 to the holder 330. In some embodiments, the holder 330 may be constructed from plastic, metal, or other suitable light blocking materials. An exemplary light blocking material includes polycarbonates. In some embodiments, the side walls 332 of the holder may be made from a light blocking material to function as light blocking layers of the bandpass filter array 320.

[0089] Embodiments of a glucose monitoring system have been described. Those skilled in the art will appreciate that various other modifications may be made within the spirit and scope of the invention. All these or other variations and modifications are contemplated by the inventors and within the scope of the invention.

What is claimed is:

1. A finger holder, comprising:

a first holder portion having a first end, a second end, and an inner surface extending from the first end to the second end;

a second holder portion having a first end, a second end, and an inner surface extending from the first end to the second end, the first ends of the first and second holder portions forming an opening to admit a finger to be received between the inner surfaces of the first and second holder portions; and

a torsion spring comprising a first arm coupled to the first holder to urge the first holder portion to the second holder portion, a second arm anchored to a support member, and a spring coil retained by a retaining post on the support member allowing the first holder portion to rotate about the retaining post thereby increasing or decreasing a size of the opening admitting the finger.

2. The finger holder of claim 1, wherein the first holder portion further comprises a retaining structure at the second end provided with a through slot for receiving the retaining post, the through slot of the retaining structure having a size allowing the first holder portion to translatively move relative to the second holder portion and the retaining post, thereby increasing or decreasing a space between the inner surfaces of the first and second holder portions.

3. The finger holder of claim 2, wherein the spring coil comprises a first coil section and a second coil section spaced apart and connected by the second arm, wherein the first and second coil sections are disposed outside of the through slot of the retaining structure and retained by the retaining post.

4. The finger holder of claim 1, wherein the first holder portion further comprises an enclosure enclosing a light source.

5. The finger holder of claim 1, wherein the first holder further comprises a stopper at the second end preventing the finger from extending beyond the finger holder.

6. The finger holder of claim 1, wherein the second holder portion further comprises a temperature sensor detecting a temperature of the finger.

7. The finger holder of claim 1, wherein the first holder portion is provided with an aperture allowing light passing through to irradiate the finger, and the second holder portion is provided with an aperture allowing light attenuated by the finger to exit through.

8. The finger holder of claim 7, wherein the second holder portion further comprises a ridge on the inner surface along the aperture of the second holder portion to position or stabilize a fingertip at the aperture of the second holder portion.

9. The finger holder of claim **1**, wherein the first and second holder portions further comprise a finger pad respectively, the finger pad is constructed from a material comprising polyurethane or liquid silicone rubber.

10. A blood monitoring system, comprising:

a light source producing light beams;

a finger holder configured to hold a finger to be irradiated by the light beams;

a detector array detecting light attenuated by the finger and generating output signals indicative of intensity of the light detected; and

a processor determining a characteristic of a blood constituent in the finger based on the generated output signals,

wherein the finger holder comprises:

a first holder portion having a first end, a second end, and an inner surface extending from the first end to the second end;

a second holder portion having a first end, a second end, and an inner surface extending from the first end to the second end, the first ends of the first and second holder portions forming an opening to admit the finger to be received between the inner surfaces of the first and second holder portions; and

a torsion spring comprising a first arm coupled to the first holder to urge the first holder portion to the second holder portion, a second arm anchored to a support member, and a spring coil retained by a retaining post on the support member allowing the first holder portion to rotate about the retaining post thereby increasing or decreasing a size of the opening admitting the finger.

11. The blood monitoring system of claim **10**, further comprising a casing enclosing the light source, the finger holder, the detector array, and the processor.

12. The blood monitoring system of claim **10**, wherein the light source is an incandescent light source.

13. The blood monitoring system of claim **10**, wherein the processor comprises a duo core processor.

14. The blood monitoring system of claim **10**, wherein the first holder portion further comprises a retaining structure at the second end provided with a through slot for receiving the retaining post, the through slot of the retaining structure having a size allowing the first holder portion to translatively move relative to the second holder portion and the retaining post, thereby increasing or decreasing a space between the inner surfaces of the first and second holder portions.

15. The blood monitoring system of claim **14**, wherein the spring coil comprises a first coil section and a second coil section spaced apart and connected by the second arm, wherein the first and second coil sections are disposed outside of the through slot of the retaining structure and retained by the retaining post.

16. The blood monitoring system of claim **10**, wherein the first holder portion further comprises an enclosure enclosing the light source.

17. The blood monitoring system of claim **10**, wherein the second holder portion further comprises a temperature sensor detecting a temperature of the finger.

18. The blood monitoring system of claim **10**, wherein the first holder portion is provided with an aperture to allow the light beams passing through to irradiate the finger, and the second holder portion is provided with an aperture to allow light attenuated by the finger to exit through.

19. The blood monitoring system of claim **18**, wherein the second holder portion further comprises a ridge on the inner surface along the aperture of the second holder portion to position or stabilize a fingertip at the aperture of the second holder portion.

20. The blood monitoring system of claim **10**, wherein the first and second holder portions further comprise a finger pad respectively, the finger pad is constructed from a material comprising polyurethane or liquid silicone rubber.

21. A bandpass filter array, comprising:

a plurality of bandpass filters arranged side by side in an array, each of the plurality of bandpass filters transmitting a spectrum of wavelengths, comprising a first end facing incident light, a second end exiting transmitted spectrum, and a first side and a second side extending from the first end to the second end, wherein the first and second sides of at least one of the plurality of bandpass filters are chamfered at the second end of the at least one of the plurality of bandpass filters; and

a plurality of light blocking layers in between neighboring bandpass filters, each of the plurality of light blocking layers extending from the first end to the second end of the plurality of bandpass filters.

22. The bandpass filter array of claim **21**, wherein each of the plurality of bandpass filters is chamfered at the second end of each of the plurality of bandpass filters.

23. The bandpass filter array of claim **21**, wherein the first and second sides of the at least one of the plurality of bandpass filters are chamfered with an angle ranging from 10 to 80 degrees.

24. The bandpass filter array of claim **21**, wherein the first and second sides of the at least one of the plurality of bandpass filters are chamfered with an angle ranging from 30 to 60 degrees.

25. The bandpass filter array of claim **21**, wherein the first and second sides of the at least one of the plurality of bandpass filters are chamfered with an angle of about 45 degrees.

26. The bandpass filter array of claim **21**, wherein the first and second sides of each of the plurality of bandpass filters are chamfered with an angle ranging from 10 to 80 degrees.

27. The bandpass filter array of claim **21**, wherein the first and second sides of each of the plurality of bandpass filters are chamfered with an angle of about 45 degrees.

28. The bandpass filter array of claim **21**, wherein each of the plurality of bandpass filters has a transmission center wavelength different from a transmission center wavelength of a neighboring bandpass filter.

29. The bandpass filter array of claim **28**, wherein the transmission center wavelengths of the plurality of bandpass filters are spread across a wavelength range from 700 to 1040 nanometers.

30. The bandpass filter array of claim **29**, wherein the transmission center wavelengths of the plurality of bandpass filters are spread across the wavelength range in a successively increased or decreased order.

31. The bandpass filter array of claim **30**, wherein the plurality of bandpass filters comprises 35 bandpass filters, each of the 35 bandpass filters has a different transmission center wavelength, and the transmission center wavelengths of the 35 bandpass filters are spread from 700 to 1040 nanometers with a wavelength step of up to 10 nanometers.

32. The bandpass filter array of claim **21**, further comprising a holder including a plurality of walls defining an array of cavities, wherein the plurality of bandpass filters are disposed in the array of cavities.

33. The bandpass filter array of claim **32**, wherein the holder is constructed from a light blocking material.

34. An optical apparatus, comprising:

a collimation lens collimating light;

a bandpass filter array selectively transmitting a spectrum of wavelengths of the collimated light; and

a detector array optically coupled to the bandpass filter array detecting the spectrum selectively transmitted by the bandpass filter array and generating output signals indicative of intensities of the spectrum detected, wherein,

the bandpass filter array comprises a plurality of bandpass filters and a plurality of light blocking layers in between neighboring bandpass filters, the detector array comprises a plurality of light-detection elements each corresponding to one of the plurality of bandpass filters;

each of the plurality of bandpass filters has a first end distal to the detector array, a second end proximal to the detector array, and a first side and a second side extending from the first end to the second end; and

the first and second sides of at least one of the plurality of bandpass filters are chamfered at the second end, thereby leading the light selectively transmitted by the at least one of the plurality of bandpass filters to the corresponding light-detection element.

35. The optical apparatus of claim **34**, wherein the first and second sides of each of the plurality of bandpass filters are chamfered at the second end of each of the plurality of bandpass filters.

36. The optical apparatus of claim **35**, wherein the first and second sides of each of the plurality of bandpass filters are chamfered with an angle ranging from 10 to 80 degrees.

37. The optical apparatus of claim **35**, wherein the first and second sides of each of the plurality of bandpass filters are chamfered with an angle of about 45 degrees.

38. The optical apparatus of claim **34**, wherein the plurality of light detection elements are spaced apart between one another, and the plurality of light blocking layers extend at least partially into spaces between the plurality of light detection elements.

39. The optical apparatus of claim **34**, wherein each of the plurality of bandpass filters has a transmission center wavelength different from a transmission center wavelength of a neighboring bandpass filter, the transmission center wavelengths of the plurality of bandpass filters spreading across a wavelength range from 700 to 1040 nanometers.

40. The optical apparatus of claim **39**, wherein the plurality of bandpass filters comprises 35 bandpass filters, the transmission center wavelengths of the 35 bandpass filters are spread from 700 to 1040 nanometers with a wavelength step of no more than 10 nanometers, and the detector array comprises 35 light-detection elements each corresponding to one of the 35 bandpass filters.

41. The optical apparatus of claim **34**, further comprising a holder including a plurality of walls defining an array of cavities, wherein the plurality of bandpass filters are disposed in the array of cavities.

42. The optical apparatus of claim **34**, further comprising a housing enclosing the collimation lens, the bandpass filter array, and the detector array, wherein the housing is provided with an optical window allowing the incident light passing therethrough to the collimating lens.

43. A blood monitoring system, comprising:

a light source producing light beams having a range of wavelengths;

a finger holder configured to hold a finger to be irradiated by the light beams;

a collimation lens collimating light transmitted through the finger;

a bandpass filter array selectively transmitting a spectrum of wavelengths of the collimated light;

a detector array optically coupled to the bandpass filter array detecting the spectrum selectively transmitted by the bandpass filter array and generating output signals indicative of intensities of the spectrum detected; and

a processor determining a characteristic of a blood constituent in the finger based on the generated output signals, wherein,

the bandpass filter array comprises a plurality of bandpass filters and a plurality of light blocking layers in between neighboring bandpass filters, the detector array comprises a plurality of light-detection elements each corresponding to one of the plurality of bandpass filters;

each of the plurality of bandpass filters has a first end distal to the detector array, a second end proximal to the detector array, and a first side and a second side extending from the first end to the second end; and

the first and second sides of at least one of the plurality of bandpass filters are chamfered at the second end, thereby leading the light selectively transmitted by the at least one of the plurality of bandpass filters to the corresponding light-detection element.

44. The blood monitoring system of claim **43**, wherein the light source is an incandescent light source.

45. The blood monitoring system of claim **43**, wherein the first and second sides of each of the plurality of bandpass filters are chamfered at the second end of each of the plurality of bandpass filters.

46. The blood monitoring system of claim **45**, wherein the first and second sides of each of the plurality of bandpass filters are chamfered with an angle ranging from 10 to 80 degrees.

47. The blood monitoring system of claim **45**, wherein the first and second sides of each of the plurality of bandpass filters are chamfered with an angle of about 45 degrees.

48. The blood monitoring system of claim **43**, wherein each of the plurality of bandpass filters has a transmission center wavelength different from a transmission center wavelength of a neighboring bandpass filter, the transmission center wavelengths of the plurality of bandpass filters spreading across a wavelength range from 700 to 1040 nanometers.

49. The blood monitoring system of claim **48**, wherein the plurality of bandpass filters comprises 35 bandpass filters, the transmission center wavelengths of the 35 bandpass filters are spread from 700 to 1040 nanometers with a wavelength step of up to 10 nanometers, and the detector array comprises 35 light detection elements each corresponding to one of the 35 bandpass filters.

50. The blood monitoring system of claim **43**, wherein the processor comprises a duo core processor.

51. The blood monitoring system of claim **43**, further comprising a casing to enclose the light source, the finger holder, the collimation lens, the bandpass filter array, the detector array, and the processor.

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摘要(译)

血液监测系统采用能够接收和稳定各种尺寸的手指的手指保持器。血液监测系统采用能够减少光学串扰的带通滤波器阵列。