PTO/AIA/15 (07-12)
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U.S. Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	9653-7IPCT
First Inventor	Steven Francis LeBoeuf
Title	Light-Guiding Devices and Monitoring Devices...
Express Mail Label No.	

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. ☐ **Fee Transmittal Form.** (PTO/SB/17 or equivalent)
2. ☐ **Applicant claims small entity status.** See 37 CFR 1.27.
3. ☑ **Specification.** [*Total Pages* 66] Both the claims and abstract must start on a new page *(For information on the preferred arrangement, see MPEP § 608.01(a))*
4. ☑ **Drawing(s).** *(35 U.S.C. 113)* [*Total Sheets* 28]
5. **Inventor's Oath or Declaration.** [*Total Sheets* 2] *(Including substitute statements under 37 CFR 1.64 and assignments serving as an oath or declaration under 37 CFR 1.63(e))*
   a. ☑ Newly executed (original or copy)
   b. ☐ A copy from a prior application (37 CFR 1.63(d))
6. ☑ **Application Data Sheet.** **See Note below.* See 37 CFR 1.76 (PTO/AIA/14 or equivalent)
7. ☐ **CD-ROM or CD-R.** In duplicate, large table or Computer Program *(Appendix)*
   ☐ Landscape Table on CD
8. **Nucleotide and/or Amino Acid Sequence Submission.** *(if applicable, items a. – c. are required)*
   a. ☐ Computer Readable Form (CRF)
   b. ☐ Specification Sequence Listing on:
      i. ☐ CD-ROM or CD-R (2 copies); or
      ii. ☐ Paper
   c. ☐ Statements verifying identity of above copies

ADDRESS TO: **Commissioner for Patents, P.O. Box 1450, Alexandria VA 22313-1450**

ACCOMPANYING APPLICATION PARTS

9. ☐ **Assignment Papers.** (cover sheet & document(s))
   Name of Assignee_____
10. ☐ **37 CFR 3.73(c) Statement.** ☑ **Power of Attorney.** *(when there is an assignee)*
11. ☐ **English Translation Document.** *(if applicable)*
12. ☑ **Information Disclosure Statement.** (PTO/SB/08 or PTO-1449)
    ☐ Copies of citations attached
13. ☐ **Preliminary Amendment.**
14. ☐ **Return Receipt Postcard.** *(MPEP § 503) (Should be specifically itemized)*
15. ☐ **Certified Copy of Priority Document(s).** *(if foreign priority is claimed)*
16. ☐ **Nonpublication Request.** Under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
17. ☐ **Other:**_____

***Note:** (1) Benefit claims under 37 CFR 1.78 and foreign priority claims under 1.55 **must** be included in an Application Data Sheet (ADS).
(2) For applications filed under 35 U.S.C. 111, the application must contain an ADS specifying the applicant if the applicant is an assignee, person to whom the inventor is under an obligation to assign, or person who otherwise shows sufficient proprietary interest in the matter. See 37 CFR 1.46(b).

18. CORRESPONDENCE ADDRESS

☑ The address associated with Customer Number: 20792 *OR* ☐ Correspondence address below

Name					
Address					
City		State		Zip Code	
Country		Telephone		Email	

Signature	N J Boddie II	Date	May 9, 2014
Name (Print/Type)	Needham J. Boddie, II	Registration No. (Attorney/Agent)	40,519

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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Application Data Sheet 37 CFR 1.76	Attorney Docket Number	9653-7IPCT
	Application Number	
Title of Invention	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME	

The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76.
This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1 Remove

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Steven	Francis	LeBoeuf	

Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

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Residence Information (Select One) ◉ US Residency ○ Non US Residency ○ Active US Military Service

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Title of Invention	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME	

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Inventor 4 — Remove

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Address 2			
City	Cary	State/Province	NC
Postal Code	27511	Country	US

All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the **Add** button. Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below.
For further information see 37 CFR 1.33(a).

☐ An Address is being provided for the correspondence Information of this application.

Customer Number	20792		
Email Address		Add Email	Remove Email

Application Information:

Title of the Invention	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME		
Attorney Docket Number	9653-7IPCT	Small Entity Status Claimed	☐
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)		Suggested Figure for Publication (if any)	

Filing By Reference :

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Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32).
Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:	◉ Customer Number	○ US Patent Practitioner	○ Limited Recognition (37 CFR 11.9)
Customer Number	20792		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.
When referring to the current application, please leave the application number blank.

Prior Application Status	Pending		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	Continuation of	13715247	2012-12-14
Prior Application Status	Patented		Remove

Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)	Patent Number	Issue Date (YYYY-MM-DD)
13715247	Continuation in part of	12691388	2010-01-21	8700111	2014-04-14

Prior Application Status	Expired	Remove

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Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
12691388	Claims benefit of provisional	61208567	2009-02-25
Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
12691388	Claims benefit of provisional	61208574	2009-02-25
Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
12691388	Claims benefit of provisional	61212444	2009-04-13
Prior Application Status	Expired		Remove
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
12691388	Claims benefit of provisional	61274191	2009-08-14

Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the **Add** button.

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(d). When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)[i] the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(h)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Remove

Application Number	Country[i]	Filing Date (YYYY-MM-DD)	Access Code[i] (if applicable)

Additional Foreign Priority Data may be generated within this form by selecting the **Add** button.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	9653-7IPCT
	Application Number	
Title of Invention	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME	

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

☐ This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.
NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Authorization to Permit Access:

☒ Authorization to Permit Access to the Instant Application by the Participating Offices

If checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the instant patent application is filed access to the instant patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the instant patent application is filed to have access to the instant patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the instant patent application with respect to: 1) the instant patent application-as-filed; 2) any foreign application to which the instant patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the instant patent application; and 3) any U.S. application-as-filed from which benefit is sought in the instant patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date o f filing this Authorization.

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

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Application Data Sheet 37 CFR 1.76	Attorney Docket Number	9653-7IPCT
	Application Number	
Title of Invention	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME	

Applicant 1

If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.

Clear

◉ Assignee	○ Legal Representative under 35 U.S.C. 117	○ Joint Inventor
○ Person to whom the inventor is obligated to assign.	○ Person who shows sufficient proprietary interest	

If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:

Name of the Deceased or Legally Incapacitated Inventor :

If the Applicant is an Organization check here. ☒

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Phone Number		Fax Number	
Email Address			

Additional Applicant Data may be generated within this form by selecting the Add button.

Assignee Information including Non-Applicant Assignee Information:

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Assignee 1

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication . An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

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	Application Number	
Title of Invention	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME	

Prefix	**Given Name**	Middle Name	**Family Name**	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1			
Address 2			
City		**State/Province**	
Country i		Postal Code	
Phone Number		Fax Number	
Email Address			

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

Signature:

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Signature	NJ Boddie II			Date (YYYY-MM-DD)	2014-05-09
First Name	Needham J.	Last Name	Boddie, II	Registration Number	40519

Additional Signature may be generated within this form by selecting the Add button.

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME

RELATED APPLICATIONS

This application is a continuation application of U.S. Patent Application Serial No. 13/715,247, filed December 14, 2012, which is a continuation-in-part of U.S. Patent Application Serial No. 12/691,388, filed January 21, 2010, now U.S. Patent No. 8,700,111, which claims the benefit of and priority to U.S. Provisional Patent Application No. 61/208,567 filed 02/25/2009, U.S. Provisional Patent Application No. 61/208,574 filed 02/25/2009, U.S. Provisional Patent Application No. 61/212,444 filed 4/13/2009, and U.S. Provisional Patent Application No. 61/274,191 filed 8/14/2009, the disclosures of which are incorporated herein by reference as if set forth in their entireties.

FIELD OF THE INVENTION

The present invention relates generally to headsets and, more particularly, to headset earbuds.

BACKGROUND OF THE INVENTION

There is growing market demand for personal health and environmental monitors, for example, for gauging overall health and metabolism during exercise, athletic training, dieting, daily life activities, sickness, and physical therapy. However, traditional health monitors and environmental monitors may be bulky, rigid, and uncomfortable – generally not suitable for use during daily physical activity. There is also growing interest in generating and comparing health and environmental exposure statistics of the general public and particular demographic groups. For example, collective statistics may enable the healthcare industry and medical community to direct healthcare resources to where they are most highly valued. However, methods of collecting these

statistics may be expensive and laborious, often utilizing human-based recording/analysis steps at multiple sites.

As such, improved ways of collecting, storing and analyzing physiological information are needed. In addition, improved ways of seamlessly extracting physiological information from a person during everyday life activities, especially during high activity levels, may be important for enhancing fitness training and healthcare quality, promoting and facilitating prevention, and reducing healthcare costs.

SUMMARY

It should be appreciated that this Summary is provided to introduce a selection of concepts in a simplified form, the concepts being further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of this disclosure, nor is it intended to limit the scope of the invention.

According to some embodiments of the present invention, a headset configured to be attached to the ear of a person includes a base, an earbud housing extending outwardly from the base that is configured to be positioned within an ear of a subject, and a cover surrounding the earbud housing. The base includes a speaker, an optical emitter, and an optical detector. The cover includes light transmissive material that is in optical communication with the optical emitter and the optical detector and serves as a light guide to deliver light from the optical emitter into the ear canal of the subject wearing the headset at one or more predetermined locations and to collect light external to the earbud housing and deliver the collected light to the optical detector. The optical emitter, via the light-guiding cover, directs optical energy towards a particular region of ear and the optical detector detects secondary optical energy emanating from the ear region. In some embodiments, the optical detector may include an optical filter configured to pass secondary optical energy at selective wavelengths. In some embodiments, the light transmissive material of the cover may be configured, for example via the use of cladding and/or light reflective material, such that the cover serves as a light guide that is coupled in parallel to the optical emitter and detector. In some embodiments, the light transmissive material of the cover may be configured, for example via the use of

cladding and/or light reflective material, such that the cover serves as a light guide that is coupled perpendicular to the optical emitter and detector.

In some embodiments, the headset may include various electronic components secured to the base. For example, the headset may include one or more environmental sensors configured to detect and/or measure environmental conditions in a vicinity of the headset. The headset may include a signal processor configured to receive and process signals produced by the optical detector. For example, in some embodiments, a signal processor may be configured to extract secondary optical energy and remove optical noise or environmental noise. The headset may include a signal processor configured to receive and process signals produced by the one or more environmental sensors. In addition, the headset may include a transmitter configured to transmit signals processed by the signal processor to a remote device in real time. Headsets according to embodiments of the present invention may utilize, for example, Bluetooth®, Wi-Fi, ZigBee, or other wireless transmitters.

In some embodiments, a housing is secured to and overlies the base so as to enclose and protect the speaker, optical emitter and optical detector, as well as other electronic components secured to the base (e.g., sensors, processor, transmitter etc.).

The earbud housing is in acoustical communication with the speaker and has at least one aperture through which sound from the speaker can pass. The light-guiding cover surrounding the earbud housing also includes at least one aperture through which sound from the speaker can pass. The cover may be formed from a soft, resilient material, such as silicone which deforms when inserted within an ear canal of a subject. In some embodiments, the cover includes an alignment member that facilitates alignment of the earbud housing within an ear canal of a subject.

Light directed into the ear of a subject from a light emitter and the subsequent collection of light at a light detector, according to embodiments of the present invention, may be utilized for detecting and/or measuring, among other things, body temperature, skin temperature, blood gas levels, muscle tension, heart rate, blood flow, cardiopulmonary functions, etc.

In some embodiments of the present invention, the light-guiding cover may include a lens that is in optical communication with the optical emitter

and/or optical detector. The lens may be configured to focus light emitted by the optical emitter and/or to focus collected light toward the optical detector. In some embodiments, multiple lenses may be incorporated into a light-guiding cover.

In some embodiments, the light-guiding cover may include a light diffusion region in optical communication with the light transmissive material that diffuses light emitted by the optical detector.

In some embodiments, the light-guiding cover may include a luminescence-generating region, such as a phosphor-containing region, that is in optical communication with the light transmissive material. The luminescence-generating region may be embedded within the light-guiding cover and/or on a surface of the light-guiding cover. The luminescence-generating region is configured to receive light emitted by the optical emitter and convert at least a portion of the received light to light having a different wavelength from that of the received light.

In some embodiments, the light-guiding cover includes one or more grooves formed therein. Each groove is configured to direct external light to the optical detector.

In some embodiments, the light transmissive material of the light-guiding cover is configured to direct light from the optical emitter to a plurality of locations at an outer surface of the cover for delivery into an ear canal of a subject.

In some embodiments, the light transmissive material of the light-guiding cover is a translucent material or includes translucent material in selected locations.

In some embodiments, a light reflective material is on at least a portion of one or both of the inner and outer surfaces of the light-guiding cover.

According to some embodiments of the present invention, a light-guiding earbud for a headset includes light transmissive material that is in optical communication with an optical emitter and optical detector associated with the headset. The light transmissive material is configured to deliver light from the optical emitter into the ear canal of a subject at one or more predetermined locations and to collect light external to the earbud housing and deliver the collected light to the optical detector. In some embodiments, the light emitter and light detector may be integral with the earbud. For example, in some

embodiments, a flexible optical emitter is incorporated within the earbud and is in optical communication with the light transmissive material.

In some embodiments, an earbud includes at least one lens in optical communication with the light transmissive material. Each lens may be configured to focus light from the optical emitter onto one or more predetermined locations in the ear of a subject and/or to focus collected external light onto the optical detector

In some embodiments of the present invention, an earbud may include luminescent material. Luminescent light is generated from optical excitation of the luminescent material by an optical emitter.

In some embodiments of the present invention, an earbud may integrate a sensor module containing a plurality of sensor elements for measuring physiological information and at least one noise source for measuring noise information. A "noise source", as used herein, refers to a sensor, such as an optical sensor, inertial sensor, electrically conductive sensor, capacitive sensor, inductive sensor, etc., and derives it name from the fact that it is a source of input to a filter, such as an adaptive filter described below.

The physiological sensors of the sensor module may generate a signal that includes physiological information plus noise information. The noise may be removed by combining the physiological information and noise information from the sensor module with noise information from the noise source of the sensor module via an electronic filtering method, such as a signal processing technique. Specific examples of such signal processing techniques include FIR (Finite Impulse Response), IIR (Infinite Impulse Response), informatics, machine learning, and adaptive filter methods. The output of the adaptive filter may be a physiological signal that is wholly or partially free of noise. In some embodiments, motion-related noise from a subject activity such as running may be removed from the physiological plus noise signal generated by a photoplethysmography (PPG) sensor for measuring blood constituent levels or blood flow properties, such as blood oxygen level, VO_2, or heart rate.

In some embodiments of the present invention, the noise source input of an adaptive filter may include a “blocked channel” of optical energy, an inertial sensor, or environmental energy. In some embodiments, the environmental energy may be unwanted ambient optical noise.

In some embodiments of the present invention, a processor/multiplexor processes physiological signals and noise signals into a data string. This data string may contain information relating to physiological information and motion-related information. The processing method may include signal processing techniques such as pre-adaptive signal conditioning, adaptive filtering, and parameter extraction.

In some embodiments, an earbud includes one or more sensor modules that includes one or more sensors for sensing physiological information and environmental information, such as noise, for example. As such, the earbud may function as a physiological monitor as well as an environmental monitor. In some embodiments, the earbud may include a microprocessor that is in electrical communication with the sensor module(s). For example, a microprocessor incorporated into an earbud may be configured to execute an adaptive filter algorithm to remove noise from at least one signal generated by a sensor module in the earbud. A microprocessor may also be configured to process information from the one or more sensors to generate a digital output string, wherein the digital output string includes a plurality of physiological and motion-related information.

Physiological sensors that may be incorporated into headsets and/or earbuds, according to some embodiments of the present invention, may be configured to detect and/or measure one or more of the following types of physiological information: heart rate, pulse rate, breathing rate, blood flow, VO_2, VO_2max, heartbeat signatures, cardio-pulmonary health, organ health, metabolism, electrolyte type and/or concentration, physical activity, caloric intake, caloric metabolism, blood metabolite levels or ratios, blood pH level, physical and/or psychological stress levels and/or stress level indicators, drug dosage and/or dosimetry, physiological drug reactions, drug chemistry, biochemistry, position and/or balance, body strain, neurological functioning, brain activity, brain waves, blood pressure, cranial pressure, hydration level, auscultatory information, auscultatory signals associated with pregnancy, physiological response to infection, skin and/or core body temperature, eye muscle movement, blood volume, inhaled and/or exhaled breath volume, physical exertion, exhaled breath physical and/or chemical composition, the presence and/or identity and/or concentration of viruses and/or bacteria, foreign

matter in the body, internal toxins, heavy metals in the body, anxiety, fertility, ovulation, sex hormones, psychological mood, sleep patterns, hunger and/or thirst, hormone type and/or concentration, cholesterol, lipids, blood panel, bone density, organ and/or body weight, reflex response, sexual arousal, mental and/or physical alertness, sleepiness, auscultatory information, response to external stimuli, swallowing volume, swallowing rate, sickness, voice characteristics, voice tone, voice pitch, voice volume, vital signs, head tilt, allergic reactions, inflammation response, auto-immune response, mutagenic response, DNA, proteins, protein levels in the blood, water content of the blood, pheromones, internal body sounds, digestive system functioning, cellular regeneration response, healing response, stem cell regeneration response, etc.

Environmental sensors that may be incorporated into headsets and/or earbuds, according to some embodiments of the present invention, may be configured to detect and/or measure one or more of the following types of environmental information: climate, humidity, temperature, pressure, barometric pressure, soot density, airborne particle density, airborne particle size, airborne particle shape, airborne particle identity, volatile organic chemicals (VOCs), hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), carcinogens, toxins, electromagnetic energy, optical radiation, X-rays, gamma rays, microwave radiation, terahertz radiation, ultraviolet radiation, infrared radiation, radio waves, atomic energy alpha particles, atomic energy beta-particles, gravity, light intensity, light frequency, light flicker, light phase, ozone, carbon monoxide, carbon dioxide, nitrous oxide, sulfides, airborne pollution, foreign material in the air, viruses, bacteria, signatures from chemical weapons, wind, air turbulence, sound and/or acoustical energy, ultrasonic energy, noise pollution, human voices, animal sounds, diseases expelled from others, exhaled breath and/or breath constituents of others, toxins from others, pheromones from others, industrial and/or transportation sounds, allergens, animal hair, pollen, exhaust from engines, vapors and/or fumes, fuel, signatures for mineral deposits and/or oil deposits, snow, rain, thermal energy, hot surfaces, hot gases, solar energy, hail, ice, vibrations, traffic, the number of people in a vicinity of the person, coughing and/or sneezing sounds from people in the vicinity of the person, loudness and/or pitch from those speaking in the vicinity of the person.

According to some embodiments of the present invention, earbuds

for headsets may include a chipset having at least one sensor element, noise source element, signal processor, input/output line, digital control, and power regulator.

Light-guiding earbuds according to the various embodiments of the present invention may be utilized with mono headsets (i.e., headsets having one earbud) as well as stereo headsets (i.e., headsets having two earbuds). Additionally, the light-guiding region of earbuds, according to embodiments of the present invention, may be integrated not only into an earbud cover and earbud housing, but also into each or all components of an earbud. Moreover, light-guiding earbuds according to the various embodiments of the present invention may be utilized with hearing aids, body jewelry, or any other attachment that can be placed near the head region, such as eye glasses or shades, a headband, a cap, helmet, visor, or the like.

According to some embodiments of the present invention, a monitoring device includes a circular band capable of encircling a finger of a subject, and a base having an optical emitter and an optical detector attached to the circular band. The circular band includes light transmissive material in optical communication with the optical emitter and optical detector that is configured to deliver light from the optical emitter to one or more portions of the finger of the subject and to collect light from one or more portions of the finger of the subject and deliver the collected light to the optical detector. In some embodiments, the circular band includes first and second concentric body portions.

In some embodiments, the circular band includes a lens region in optical communication with the optical emitter that focuses light emitted by the optical emitter and/or that collects light reflected from a finger. In some embodiments the circular band includes a phosphor-containing region in optical communication with the light transmissive material, wherein the phosphor-containing region receives light emitted by the optical emitter and converts at least a portion of the received light to light having a different wavelength from the received light.

In some embodiments, the light transmissive material of the circular band has an outer surface and an inner surface, and a cladding material, such as light reflective material, is on (or near) at least a portion of one or both of the inner and outer surfaces.

In some embodiments, the base includes one or more of the following: a signal processor configured to receive and process signals produced by the optical detector, a transmitter configured to transmit signals processed by the signal processor to a remote device.

According to some embodiments of the present invention, a monitoring device configured to be attached to the body of a subject includes a base having an optical emitter and an optical detector, and light transmissive material attached to the base. The light transmissive material is in optical communication with the optical emitter and optical detector and is configured to deliver light from the optical emitter to one or more portions of the body of the subject and to collect light from one or more portions of the body of the subject and deliver the collected light to the optical detector. The light transmissive material may include adhesive material in one or more locations that is configured to adhesively secure the device to the body of the subject.

In some embodiments, an outer body portion is attached to the base and to the light transmissive material. The outer body portion may include adhesive material in one or more locations that is configured to adhesively secure the device to the body of the subject.

In some embodiments, the light transmissive material includes a lens region that is in optical communication with the optical emitter and that focuses light emitted by the optical emitter and/or that collects light reflected from a finger. In some embodiments, the light transmissive material includes a phosphor-containing region that receives light emitted by the optical emitter and converts at least a portion of the received light to light having a different wavelength from the received light. In some embodiments, the light transmissive material has an outer surface and an inner surface, and a light reflective material is disposed on or near at least a portion of one or both of the inner and outer surfaces.

In some embodiments, the base includes one or more of the following: a signal processor configured to receive and process signals produced by the optical detector, a transmitter configured to transmit signals processed by the signal processor to a remote device.

According to some embodiments of the present invention, a headset includes a housing that is configured to be positioned within an ear of a

subject, an optical emitter, an optical detector, and at least one light guide associated with the housing. The headset may include a speaker disposed within the housing, and the housing may include at least one aperture through which sound from the speaker can pass. The headset may also include a signal processor that is configured to receive and process signals produced by the optical detector.

The at least one light guide includes a distal end that is configured to engage (or be positioned adjacent) a portion of the ear of the subject. An opposite end of the at least one light guide is in optical communication the optical emitter or optical detector. As such, the at least one light guide is configured to deliver light from the optical emitter into an ear region of the subject via the distal end or collect light from an ear region of the subject via the distal end or deliver collected light to the optical detector. In some embodiments, the optical emitter and optical detector may each have one or more respective light guides in optical communication therewith.

In some embodiments, the at least one light guide has a distal end portion that extends outwardly from the housing. In other embodiments, the at least one light guide has a distal end portion that is substantially flush with the housing or is recessed within the housing.

In some embodiments of the present invention, the optical emitter and optical detector are attached to the housing, such as the housing of the earbud itself. In other embodiments, the optical emitter and/or optical detector are located remotely from the housing. For example, the optical emitter and/or optical detector may be located on a headband, back-bar, back-band, ear hook, or any other structure that is a part of the headset. Moreover, the optical emitter and optical detector may be located at different respective locations anywhere on the headset. The at least one light guide extends from the remotely located optical emitter and/or optical detector and to the housing such that a distal end thereof can engage (or be positioned adjacent) a portion of the ear of the subject.

The at least one light guide may be formed from various types of light transmissive material, typically with a refractive index of at least one (1), and may have various shapes and configurations. For example, in some embodiments, the at least one light guide has an elongated, generally cylindrical

configuration. In some embodiments, the at least one light guide comprises an elastomeric light transmissive material. In other embodiments, the at least one light guide comprises a substantially rigid light transmissive material. In some embodiments, the at least one light guide may be surrounded or partially surrounded by a cladding material that is configured to at least partially confine light within the light guide and/or block light from an external source from entering the at least one light guide. The cladding material may be a light blocking material and/or a light reflective material, such as a black or silver coating on one or more portions of the surface of the at least one light guide.

In some embodiments, a light blocking material is positioned between the optical emitter and detector such that the optical emitter and detector are not in direct optical communication with each other.

In some embodiments, optical coupling material is applied to the optical emitter and the at least one light guide is in optical communication with the optical emitter via the optical coupling material.

In some embodiments, optical coupling material is applied to the optical detector and the at least one light guide is in optical communication with the optical detector via the optical coupling material.

In some embodiments, a plurality of light guides are utilized, each having a distal end that engages a respective different portion of the ear of a subject.

In some embodiments, the headset includes a plurality of optical emitters and a plurality of light guides. The plurality of light guides are in optical communication with the plurality of optical emitters and are configured to deliver light from the plurality of optical emitters to an ear region of the subject.

In some embodiments, the headset includes a plurality of optical detectors and a plurality of light guides. The plurality of light guides are in optical communication with the plurality of optical detectors and configured to collect light from an ear region of the subject and deliver collected light to the plurality of optical detectors.

According to other embodiments of the present invention, a headset includes a housing configured to be positioned within an ear of a subject, an optical emitter, an optical detector, and first and second light guides associated with the housing. The headset may include a speaker disposed within

the housing, and the housing may include at least one aperture through which sound from the speaker can pass. The headset may also include a signal processor that is configured to receive and process signals produced by the optical detector.

Each of the first and second light guides includes a distal end that is configured to engage (or be positioned adjacent) a respective portion of the ear of the subject. The first light guide is in optical communication with the optical emitter and is configured to deliver light from the optical emitter into an ear region of the subject via the first light guide distal end. The second light guide is in optical communication with the optical detector and is configured to collect light from an ear region of the subject via the second light guide distal end and deliver collected light to the optical detector.

In some embodiments, the distal end of the first and/or second light guides extends outwardly from the housing. In other embodiments, the distal end of the first and/or second light guides is substantially flush with the housing or is recessed within the housing.

In some embodiments of the present invention, the optical emitter and optical detector are attached to the housing. In other embodiments, the optical emitter and/or optical detector are located remotely from the housing. For example, the optical emitter and optical detector may be located on a headband or other structure that is a part of the headset. The first and second light guides extend from the remotely located optical emitter and optical detector and to the housing such that a distal end of each can engage (or be positioned adjacent) a respective portion of the ear of the subject.

The first and second light guides may be formed from various types of light transmissive material, typically with a refractive index of at least one (1), and may have various shapes and configurations. For example, in some embodiments, one or both of the first and second light guides have an elongated, generally cylindrical configuration. In some embodiments, one or both of the first and second light guides may comprise an elastomeric light transmissive material. In other embodiments, one or both of the first and second light guides may comprise a substantially rigid light transmissive material. Examples of suitable soft or elastomeric materials may include, but are not limited to, silicone, rubber, polymer-based materials, latex, lower durometer

plastics, and the like. Examples of suitable rigid materials may include, but are not limited to, polyurethane, polymer-based materials, resins, higher durometer plastics, polycarbonate, acrylic, and the like.

In some embodiments, one or both of the first and second light guides may be surrounded or may be partially surrounded by a cladding material that is configured to block light from an external source and/or at least partially confine light within one or both of the first and second light guides. The cladding material may be a light blocking material and/or a light reflective material. In some embodiments, the cladding material may be a coating, such as a black, mylar, gold, or silver coating, or a textured surface, on one or more portions of the surface of the first and second light guides. In some embodiments, the cladding may be a texturized or specially treated surface of the light guide itself, such as a micro- or nano-structured surface or an electrochemically or chemically treated surface. Surface texturing can be used to scatter internal light back within the light guide or to scatter external light away from the light guide.

In some embodiments, the light guide may also be and/or comprise an optical filter. This may provide a structure that provides both light guiding of the desired wavelengths and light blocking of undesired wavelengths. For example, the light-guide may comprise a material having an optically filtering dye or a material which inherently filters one or more wavelengths of light. For example, a light-absorptive dye, many of which are well-known in the art, may be integrated within or coated on top a polycarbonate or acrylic sheet. Similarly, a light-absorptive dye may be integrated within a resin which may then be molded into one or more light guides. A few non-limiting examples of an inherently filtering material includes sapphire, which absorbs some infrared (IR) wavelengths, or glass, which absorbs some ultraviolet (UV) wavelengths. However, various types of filtering material may be utilized, without limitation.

According to other embodiments of the present invention, a headset includes a housing configured to be positioned within an ear of a subject, an optical emitter, an optical detector, and a light guide associated with the housing. The headset may include a speaker disposed within the housing, and the housing may include at least one aperture through which sound from the speaker can pass. The headset may also include
a signal processor that is configured to receive and process signals produced by

the optical detector.

The light guide includes a distal end that is configured to engage (or be positioned adjacent) a portion of the ear of the subject. An opposite end of the light guide is in optical communication with the optical emitter and the optical detector. As such, the light guide is configured to deliver light from the optical emitter into an ear region of the subject via the light guide distal end, and to collect light from the ear region of the subject via the light guide distal end and deliver collected light to the optical detector.

In some embodiments, the light guide has a distal end portion that extends outwardly from the housing. In other embodiments, the light guide has a distal end portion that is substantially flush with the housing or is recessed within the housing.

In some embodiments of the present invention, the optical emitter and optical detector are attached to the housing. In other embodiments, the optical emitter and/or optical detector are located remotely from the housing. For example, the optical emitter and/or optical detector may be located on a headband or any other structure that is a part of the headset. Moreover, the optical emitter and optical detector may be located at different respective locations anywhere on the headset. The light guide extends from the remotely located optical emitter and optical detector and to the housing such that a distal end thereof can engage (or be positioned adjacent) a portion of the ear of the subject.

The light guide may be formed from various types of light transmissive material, typically with a refractive index of at least one (1), and may have various shapes and configurations. For example, in some embodiments, the light guide has an elongated, generally cylindrical configuration. In some embodiments, the light guide comprises an elastomeric light transmissive material. In other embodiments, the light guide comprises a substantially rigid light transmissive material. In some embodiments, the light guide may be surrounded or partially surrounded by a cladding material that is configured to block light from an external source from entering the at least one light guide and/or at least partially confine light within the light guide. The cladding material may be a light blocking material and/or a light reflective material, such as a black or silver coating on one or more portions of the surface

of the light guide.

According to other embodiments of the present invention, a wearable sensor module includes a housing configured to be worn by a subject, an optical emitter, an optical detector, and at least one light guide extending outwardly from the housing. The at least one light guide includes a distal end that is configured to engage (or be positioned adjacent) a skin region of the subject. An opposite end of the at least one light guide is in optical communication with the optical emitter or optical detector. As such, the at least one light guide is configured to deliver light from the optical emitter into a skin region the subject via the distal end or collect light from a skin region of the subject via the distal end and deliver collected light to the optical detector. In some embodiments, the optical emitter and optical detector may each have one or more respective light guides in optical communication therewith.

In some embodiments of the present invention, the optical emitter and optical detector are attached to the housing. In other embodiments, the optical emitter and/or optical detector are located remotely from the housing.

The at least one light guide may be formed from various types of light transmissive material, typically with a refractive index of at least one (1), and may have various shapes and configurations. For example, in some embodiments, the at least one light guide has an elongated, generally cylindrical configuration. In some embodiments, the at least one light guide comprises an elastomeric light transmissive material. In other embodiments, the at least one light guide comprises a substantially rigid light transmissive material. In some embodiments, the at least one light guide may be surrounded or partially surrounded by a cladding material that is configured to block light from an external source from entering the at least one light guide and/or at least partially confine light within the at least one light guide.

In some embodiments, light blocking material is positioned between the optical emitter and detector such that the optical emitter and detector are not in direct optical communication with each other.

In some embodiments, optical coupling material is applied to the optical emitter and the at least one light guide is in optical communication with the optical emitter via the optical coupling material.

In some embodiments, optical coupling material is applied to the

optical detector and the at least one light guide is in optical communication with the optical detector via the optical coupling material.

It is noted that aspects of the invention described with respect to one embodiment may be incorporated in a different embodiment although not specifically described relative thereto. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination. Applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to be able to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner. These and other objects and/or aspects of the present invention are explained in detail below.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which form a part of the specification, illustrate various embodiments of the present invention. The drawings and description together serve to fully explain embodiments of the present invention.

Fig. 1 is an exploded perspective view of a headset with a light-guiding earbud, according to some embodiments of the present invention.

Fig. 2 is a perspective view of a stereo headset incorporating light-guiding earbuds, according to some embodiments of the present invention.

Fig. 3 is a side section view of a light-guiding earbud for a headset, according to some embodiments of the present invention.

Figs. 4A-4D are side section views of light-guiding earbuds for a headset, according to some embodiments of the present invention.

Fig. 5 is a side section view of a light-guiding earbud for a headset, according to some embodiments of the present invention.

Fig. 6 is a side section view of a light-guiding earbud for a headset, according to some embodiments of the present invention..

Fig. 7A is a side section view of a light-guiding earbud for a headset, according to some embodiments of the present invention.

Fig. 7B is a perspective view of a flexible optical emitter utilized in the earbud of Fig. 7A, according to some embodiments of the present invention.

Fig. 8A is a side section view of a light-guiding earbud for a headset, according to some embodiments of the present invention.

Fig. 8B is a cross-sectional view of the earbud of Fig. 8A taken along lines 8B-8B.

Fig. 8C is a side section view of a light-guiding earbud for a headset, according to some embodiments of the present invention.

Fig. 8D is a side section view of a light-guiding earbud for a headset, according to some embodiments of the present invention.

Fig. 9A is a side section view of a light-guiding earbud for a headset, according to some embodiments of the present invention.

Fig. 9B is a cross-sectional view of the earbud of Fig. 9A taken along lines 9B-9B.

Fig. 9C illustrates luminescent particles within the earbud cover of Figs. 9A-9B, according to some embodiments of the present invention.

Fig. 9D is a side section view of a light-guiding earbud for a headset, according to some embodiments of the present invention.

Fig. 9E is a cross-sectional view of the earbud of Fig. 9D taken along lines 9E-9E.

Fig. 10 illustrates various anatomy of a human ear.

Fig. 11A is a side section view of a light-guiding earbud for a headset, according to some embodiments of the present invention.

Fig. 11B is a cross-sectional view of the earbud of Fig. 11A taken along lines 11B-11B.

Figs. 12A-12B illustrate respective opposite sides of a sensor module that may be located near the periphery of an earbud, according to some embodiments of the present invention.

Fig. 13 illustrates an adaptive filter and noise source for removing noise from a noisy physiological signal, according to some embodiments of the present invention.

Figs. 14A-14D are respective graphs of time-dependent data collected from a light-guiding earbud worn by a person, according to some embodiments of the present invention.

Fig. 15 is a graph of processed physiological signal data from a headset having one or more light-guiding earbuds, according to some embodiments of the present invention.

Fig. 16 is a flow chart of operations for extracting physiological

information from headset sensor signals, according to some embodiments of the present invention.

Fig. 17 is a block diagram that illustrates sensor signals being processed into a digital data string including activity data and physiological data, according to some embodiments of the present invention.

Fig. 18 illustrates a digital data string, according to some embodiments of the present invention.

Fig. 19 illustrates the optical interaction between the sensor module of Figs. 12A-12B and the skin of a subject.

Fig. 20 illustrates a chipset for use in a headset, according to some embodiments of the present invention.

Fig. 21 illustrates a chipset for use in a stereo headset, according to some embodiments of the present invention.

Fig. 22A is a top plan view of a monitoring device configured to be attached to finger of a subject, according to some embodiments of the present invention.

Fig. 22B is a cross-sectional view of the monitoring device of Fig. 22A taken along lines 22B-22B.

Fig. 23 is a side view of a monitoring device configured to be attached to the body of a subject, according to some embodiments of the present invention.

Figs. 24A and 24B are perspective views of a headset having light guides extending from a housing thereof, according to some embodiments of the present invention, and wherein the light guides are in optical communication with an optical emitter and optical detector.

Figs. 25A and 25B are perspective views of a headset having light guides extending from a housing thereof, according to some embodiments of the present invention, and wherein the light guides are in optical communication with an optical emitter and optical detector.

Figs. 26-29 are illustrate various light guide configurations that may be utilized within headsets and sensor modules, according to some embodiments of the present invention.

Fig. 30 is an enlarged cross-sectional view of a light guide with a layer of cladding material surrounding the light guide, according to some

embodiments of the present invention.

Fig. 31 illustrates elongated light guides that may be utilized with headsets and sensor modules, according to some embodiments of the present invention, such that an optical emitter and/or optical detector can be located remotely from the housing of a headset or sensor module.

Fig. 32 is a perspective view of a stereo headset wherein an optical emitter and optical detector are located remotely from the earbuds and wherein light guides extend from the optical emitter and optical detector to an earbud, according to some embodiments of the present invention.

Fig. 33 is an enlarged perspective view of an earbud of the headset of Fig. 32 and illustrating the exposed distal ends of the light guides of Fig. 32.

Fig. 34 is a perspective view of a headset having light guides, according to some embodiments of the present invention, and wherein the light guides are in optical communication with an optical emitter and optical detector.

Fig. 35 is an exploded perspective view of a headset with an earbud housing having a plurality of light guides associated therewith, according to some embodiments of the present invention.

Fig. 36 is a perspective view of a headset with an earbud housing having light guides associated therewith, according to some embodiments of the present invention.

Fig. 37 is a cross sectional view of the headset of Fig. 36 taken along lines A-A.

Fig. 38 is an enlarged partial view of the headset of Fig. 37.

Fig. 39 is a perspective view of a headset with an earbud housing having light guides associated therewith, according to some embodiments of the present invention.

Fig. 40 is an exploded perspective view of the headset of Fig. 39.

DETAILED DESCRIPTION

The present invention will now be described more fully hereinafter with reference to the accompanying figures, in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Like numbers refer to like elements throughout. In the figures,

certain layers, components or features may be exaggerated for clarity, and broken lines illustrate optional features or operations unless specified otherwise. In addition, the sequence of operations (or steps) is not limited to the order presented in the figures and/or claims unless specifically indicated otherwise. Features described with respect to one figure or embodiment can be associated with another embodiment or figure although not specifically described or shown as such.

It will be understood that when a feature or element is referred to as being "on" another feature or element, it can be directly on the other feature or element or intervening features and/or elements may also be present. In contrast, when a feature or element is referred to as being "directly on" another feature or element, there are no intervening features or elements present. It will also be understood that, when a feature or element is referred to as being "connected", "attached" or "coupled" to another feature or element, it can be directly connected, attached or coupled to the other feature or element or intervening features or elements may be present. In contrast, when a feature or element is referred to as being "directly connected", "directly attached" or "directly coupled" to another feature or element, there are no intervening features or elements present. Although described or shown with respect to one embodiment, the features and elements so described or shown can apply to other embodiments. It will also be appreciated by those of skill in the art that references to a structure or feature that is disposed "adjacent" another feature may have portions that overlap or underlie the adjacent feature.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, steps, operations, elements, components, and/or groups thereof. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

Spatially relative terms, such as "under", "below", "lower", "over",

"upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if a device in the figures is inverted, elements described as "under" or "beneath" other elements or features would then be oriented "over" the other elements or features. Thus, the exemplary term "under" can encompass both an orientation of over and under. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly. Similarly, the terms "upwardly", "downwardly", "vertical", "horizontal" and the like are used herein for the purpose of explanation only unless specifically indicated otherwise.

It will be understood that although the terms first and second are used herein to describe various features/elements, these features/elements should not be limited by these terms. These terms are only used to distinguish one feature/element from another feature/element. Thus, a first feature/element discussed below could be termed a second feature/element, and similarly, a second feature/element discussed below could be termed a first feature/element without departing from the teachings of the present invention. Like numbers refer to like elements throughout.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the specification and relevant art and should not be interpreted in an idealized or overly formal sense unless expressly so defined herein. Well-known functions or constructions may not be described in detail for brevity and/or clarity.

The term "headset", as used herein, is intended to include any type of device or earpiece that may be attached to or near the ear (or ears) of a user and may have various configurations, without limitation. Headsets incorporating light-guiding earbuds, as well as light guides, as described herein may include

mono headsets (a device having only one earbud, one earpiece, etc.) and stereo headsets (a device having two earbuds, two earpieces, etc.), earbuds, hearing aids, ear jewelry, face masks, headbands, and the like. In some embodiments, the term "headset" may include broadly headset elements that are not located on the head but are associated with the headset. For example, in a "medallion" style wireless headset, where the medallion comprises the wireless electronics and the headphones are plugged into or hard-wired into the medallion, the wearable medallion would be considered part of the headset as a whole. Similarly, in some cases, if a mobile phone or other mobile device is intimately associated with a plugged-in headphone, then the term "headset" may refer to the headphone-mobile device combination.

The term "real-time" is used to describe a process of sensing, processing, or transmitting information in a time frame which is equal to or shorter than the minimum timescale at which the information is needed. For example, the real-time monitoring of pulse rate may result in a single average pulse-rate measurement every minute, averaged over 30 seconds, because an instantaneous pulse rate is often useless to the end user. Typically, averaged physiological and environmental information is more relevant than instantaneous changes. Thus, in the context of the present invention, signals may sometimes be processed over several seconds, or even minutes, in order to generate a "real-time" response.

The term "monitoring" refers to the act of measuring, quantifying, qualifying, estimating, sensing, calculating, interpolating, extrapolating, inferring, deducing, or any combination of these actions. More generally, "monitoring" refers to a way of getting information via one or more sensing elements. For example, "blood health monitoring" includes monitoring blood gas levels, blood hydration, and metabolite/electrolyte levels.

The term "physiological" refers to matter or energy of or from the body of a creature (*e.g.*, humans, animals, etc.). In embodiments of the present invention, the term "physiological" is intended to be used broadly, covering both physical and psychological matter and energy of or from the body of a creature. However, in some cases, the term "psychological" is called-out separately to emphasize aspects of physiology that are more closely tied to conscious or subconscious brain activity rather than the activity of other organs, tissues, or

cells.

The term "body" refers to the body of a subject (human or animal) that may wear a headset incorporating one or more light-guiding earbuds, according to embodiments of the present invention.

In the following figures, various headsets and light-guiding earbuds for use with headsets will be illustrated and described for attachment to the ear of the human body. However, it is to be understood that embodiments of the present invention are not limited to those worn by humans.

The ear is an ideal location for wearable health and environmental monitors. The ear is a relatively immobile platform that does not obstruct a person's movement or vision. Headsets located at an ear have, for example, access to the inner-ear canal and tympanic membrane (for measuring core body temperature), muscle tissue (for monitoring muscle tension), the pinna and earlobe (for monitoring blood gas levels), the region behind the ear (for measuring skin temperature and galvanic skin response), and the internal carotid artery (for measuring cardiopulmonary functioning), etc. The ear is also at or near the point of exposure to: environmental breathable toxicants of interest (volatile organic compounds, pollution, etc.; noise pollution experienced by the ear; and lighting conditions for the eye. Furthermore, as the ear canal is naturally designed for transmitting acoustical energy, the ear provides a good location for monitoring internal sounds, such as heartbeat, breathing rate, and mouth motion.

Wireless, Bluetooth®-enabled, and/or other personal communication headsets may be configured to incorporate physiological and/or environmental sensors, according to some embodiments of the present invention. As a specific example, Bluetooth® headsets are typically lightweight, unobtrusive devices that have become widely accepted socially. Moreover, Bluetooth® headsets are cost effective, easy to use, and are often worn by users for most of their waking hours while attending or waiting for cell phone calls. Bluetooth® headsets configured according to embodiments of the present invention are advantageous because they provide a function for the user beyond health monitoring, such as personal communication and multimedia applications, thereby encouraging user compliance. Exemplary physiological and environmental sensors that may be incorporated into a Bluetooth® or other type of headsets include, but are not limited to accelerometers, auscultatory sensors,

pressure sensors, humidity sensors, color sensors, light intensity sensors, pressure sensors, etc.

Headsets, both mono (single earbud) and stereo (dual earbuds), incorporating low-profile sensors and other electronics, according to embodiments of the present invention, offer a platform for performing near-real-time personal health and environmental monitoring in wearable, socially acceptable devices. The capability to unobtrusively monitor an individual's physiology and/or environment, combined with improved user compliance, is expected to have significant impact on future planned health and environmental exposure studies. This is especially true for those that seek to link environmental stressors with personal stress level indicators. The large scale commercial availability of this low-cost device can enable cost-effective large scale studies. The combination of monitored data with user location via GPS data can make on-going geographic studies possible, including the tracking of infection over large geographic areas. The commercial application of the proposed platform encourages individual-driven health maintenance and promotes a healthier lifestyle through proper caloric intake and exercise.

Accordingly, some embodiments of the present invention combine a personal communications headset device with one or more physiological and/or environmental sensors. Other embodiments may combine physiological and/or environmental sensors into a headset device.

Optical coupling into the blood vessels of the ear may vary between individuals. As used herein, the term "coupling" refers to the interaction or communication between excitation light entering a region and the region itself. For example, one form of optical coupling may be the interaction between excitation light generated from within a light-guiding earbud and the blood vessels of the ear. In one embodiment, this interaction may involve excitation light entering the ear region and scattering from a blood vessel in the ear such that the intensity of scattered light is proportional to blood flow within the blood vessel. Another form of optical coupling may be the interaction between excitation light generated by an optical emitter within an earbud and the light-guiding region of the earbud. Thus, an earbud with integrated light-guiding capabilities, wherein light can be guided to multiple and/or select regions along the earbud, can assure that each individual wearing the earbud will generate an

optical signal related to blood flow through the blood vessels. Optical coupling of light to a particular ear region of one person may not yield photoplethysmographic signals for each person. Therefore, coupling light to multiple regions may assure that at least one blood-vessel-rich region will be interrogated for each person wearing the light-guiding earbud. Coupling multiple regions of the ear to light may also be accomplished by diffusing light from a light source within the earbud.

Embodiments of the present invention are not limited to headsets that communicate wirelessly. In some embodiments of the present invention, headsets configured to monitor an individual's physiology and/or environment may be wired to a device that stores and/or processes data. In some embodiments, this information may be stored on the headset itself. Furthermore, embodiments of the present invention are not limited to earbuds. In some embodiments, the light-guiding structure may be molded around another part of the body, such as a digit, finger, toe, limb, around the nose or earlobe, or the like. In other embodiments, the light-guiding structure may be integrated into a patch, such as a bandage that sticks on a person's body.

Referring to Fig. 1, a headset 10 according to some embodiments of the present invention is illustrated. The illustrated headset 10 includes a base 12, a headset housing 14, an earbud housing 16, and a cover 18 that surrounds the earbud housing 16. The base 12 includes a main circuit board 20 that supports and/or is connected to various electronic components. In the illustrated embodiment, a speaker 22, optical emitter 24, optical detectors 26, and thermopile 28 (described below) are mounted onto a secondary circuit board 32 which is secured to the main circuit board 20. The earbud housing surrounds the speaker 22, optical emitter 24, optical detectors 26, and thermopile 28. Collectively, the earbud housing 16, cover 18, and various electronic components (e.g., speaker 22, optical emitter 24, optical detectors 26, thermopile 28) located within the earbud housing 16 of the illustrated headset 10 may be referred to as an earbud 30. The headset housing 14 is secured to the base 12 and is configured to enclose and protect the various electronic components mounted to the base (e.g., main circuit board 20 and components secured thereto, etc.) from ambient interference (air, humidity, particulates, electromagnetic interference, etc).

Each optical detector 26 may be a photodiode, photodetector, phototransistor, thyristor, solid state device, optical chipset, or the like. The optical emitter 24 may be a light-emitting diode (LED), laser diode (LD), compact incandescent bulb, micro-plasma emitter, IR blackbody source, or the like. The speaker 22 may be a compact speaker, such as an inductive speaker, piezoelectric speaker, electrostatic speaker, or the like. One or more microphones, such as electrets, MEMS, acoustic transducers, or the like, may also be located within the headset housing or earbud housing to pick up speech, physiological sounds, and/or environmental sounds.

The main circuit board 20 and secondary circuit board 32 may also support one or more sensor modules (not shown) that contain various physiological and/or environmental sensors. For example, a sensor module, such as sensor module 70 illustrated in Figs. 12A-12B, may be attached to the circuit boards 20, 32. The circuit boards 20, 32 also may include at least one signal processor (not shown), at least one wireless module (not shown) for communicating with a remote device, and/or at least one memory storage device (not shown). An exemplary wireless module may include a wireless chip, antenna, or RFID tag. In some embodiments, the wireless module may include a low-range wireless chip or chipset, such as a Bluetooth® or ZigBee chip. These electronic components may be located on the main circuit board 20, or on another circuit board, such as the secondary circuit board 32, attached to the main circuit board.

Secondary circuit board 32 may also include a temperature sensor, such as a thermopile 28 mounted thereto. The thermopile 28 is oriented so as to point towards the tympanic membrane within the ear of a subject wearing the headset 10 through the acoustic orifices 34a, 34b in the earbud housing 16 and cover 18, respectively. The secondary circuit board 32 may be in electrical contact with the main circuit board 20 via soldering, connectors, wiring, or the like. A battery 36, such as a lithium polymer battery or other portable battery, may be mounted to the main circuit board 20 and may be charged via a USB charge port 38. Although not shown in Fig. 1, an ear hook may be attached to the base 12 or housing 14 to help stabilize the earbud 30 and headset 10 worn by a subject and such that the earbud 30 is consistently placed at the same location within the ear canal of a subject.

In the illustrated embodiment, the earbud housing 16 is in acoustical communication with the speaker 22 and includes an aperture 34a through which sound from the speaker 22 can pass. However, additional apertures may also be utilized. The cover 18 also includes at least one aperture 34b through which sound from the speaker 22 can pass. The thermopile 28 is used as a heat sensor and measures thermal radiation from the ear of a subject via the acoustic apertures 34a, 34b. Additional or other sensors may be in the location of the thermopile 28, aligned towards the tympanic membrane, to sense other forms of energy, such as acoustic, mechanical, chemical, optical, or nuclear energy from the tympanic membrane region. For example, a photodetector may replace the thermopile 28 to measure light scattering off the tympanic membrane.

The cover 18 includes light transmissive material in a portion 19 thereof that is referred to as a light-guiding region. The light transmissive material in light-guiding region 19 is in optical communication with the optical emitter 24 and detectors 26. The light transmissive material in light-guiding region 19 is configured to deliver light from the optical emitter 24 into an ear canal of the subject at one or more predetermined locations and to collect light external to the earbud 30 and deliver the collected light to the optical detectors 26. As such, the earbud 30 of the illustrated headset 10 is referred to as a "light-guiding" earbud 30.

In some embodiments, the light transmissive material in the light-guiding region 19 may include a lens (e.g., lens 18L illustrated in Fig. 6). The lens 18L is in optical communication with the optical emitter 24 and/or with the optical detectors 26. For example, a lens 18L may be configured to focus light emitted by the optical emitter 24 onto one or more portions of an ear and/or to focus collected light on the light detectors 26. Lenses are described below with respect to Figs. 5-6.

In some embodiments, the earbud cover 18 may integrate a transparent light-guiding layer, wherein air is utilized as a cladding layer. For example, the earbud cover 18 may include an optically transparent silicone molded layer, and the earbud housing 16 may be removed such that a cladding layer is air. In some embodiments, the earbud housing 16 may be closed, and the light-guiding region 19 may be integrated within the cover 18 or between the

housing 16 and cover 18.

The illustrated cover 18 of Fig. 1 includes an alignment member 40 (also referred to as a stabilization arm) that facilitates alignment of the earbud 30 within an ear canal of a subject. The alignment member 40 may facilitate stable measurements of optical scattered light from the ear region, which can be important for PPG measurements and tympanic temperature measurements.

In some embodiments, a light-guiding cover 18 is formed from a soft, resilient material, such as silicone, which deforms when inserted within an ear canal of a subject. However, various materials may be utilized for light-guiding covers 18 and for serving as light guides depending on the type of earbud desired for a particular use case, according to embodiments of the present invention. For example, in some embodiments, a light-guiding cover 18 may be formed from a substantially rigid material such that the light-guiding earbud 30 is substantially rigid. For example, for a running use case, the runner may wish to have firm but soft earbuds, such that the earbud may deform to some extent when inserted into the ear. In such case, the light-guiding region may be silicone or other soft material and the outer cladding may be air, a polymer, plastic, or a soft material having a lower index of refraction than silicone.

Fig. 2 illustrates a stereo headset 100 that utilizes two light-guiding earbuds 130, according to some embodiments of the present invention. The headset 100 also includes various sensor elements 132 located at several regions in the stereo headset 100. A benefit of the stereo headset 100 may be that the total number of sensors measuring the ear region may be doubled; alternatively, the sensors in each earbud may be halved. Another benefit of the stereo headset is that it may enable stereo music during daily activities. Another benefit of the stereo headset is that asymmetric physiological differences can be detected in the user by measuring each side of the user in real-time. For example, differences in blood flow between right and left sides of a user may be detected, indicating changes in right/left brain activity, the onset of a stroke, localized inflammation, or the like.

Light-guiding earbuds according to various embodiments of the present invention will now be described with respect to Figs. 3, 4A-4D, 5, 6, 7A-7B, 8A-8D, 9A-9B, and 11A-11B. Referring initially to Figs. 3-4, a light-guiding

earbud 30 includes a base 50, an earbud housing 16 extending outwardly from the base 50 that is configured to be positioned within an ear E of a subject, and a cover 18 that surrounds the earbud housing 16. The earbud housing 16 is in acoustical communication with a speaker 22 and includes at least one aperture 34a through which sound from the speaker 22 can pass. The cover 18 includes at least one aperture 34b through which sound from the speaker 22 can pass, and includes light transmissive material in optical communication with an optical emitter 24 and detector 26.

The cover 18 includes cladding material 21 on an inner surface 18b thereof and on an outer surface 18a thereof, as illustrated. An end portion 18f of the cover outer surface 18a does not have cladding material. As such, the cover 18 serves as a light guide that delivers light from the optical emitter 24 through the end portion 18f and into the ear canal C of a subject at one or more predetermined locations and that collects light external to the earbud housing 16 and delivers the collected light to the optical detector 26. In the various embodiments described herein, the terms light guide and cover are intended to be interchangeable. However, it should be noted that, in other embodiments, the earbud housing 16 may also serve as a light guide without the need for cover 18.

The base 50 in all of the earbud embodiments (Figs. 3, 4A-4D, 5, 6, 7A-7B, 8A-8D, 9A-9B, 11A-11B, 24A-24B, 25A-25B, 26-29, 31, and 34) described herein may include any combination of a printed circuit board, electrical connectors, and housing component for a headset. For example, the base 50 in Figs. 3-6, 7A-7B, 8A-8D, 9A-9B, 11A-11B, 24A-24B, 25A-25B, 26-29, 31, and 34 may include, for example, the base 12 of the headset 10 of Fig. 1, the main circuit board 20 of the headset 10 of Fig. 1, the housing 14 of the headset 10 of Fig. 1, or may be a combination of the base 12, main circuit board 20, and/or housing 14 of the headset 10 of Fig. 1.

The optical emitter 24 generates inspection light 111 and the light-guiding region 19 of the light guide 18 directs the inspection light 111 towards an ear region. This light is called inspection light because it interrogates the surface of the ear, penetrates the skin of the ear, and generates a scattered light response 110 which may effectively inspect blood vessels within the ear region. The optical detector 26 detects scattered light 110 from an ear region and the light-guiding region 19 of the light guide 18 guides the light to the optical detector

26 through the light-guiding region 19, as illustrated.

In the embodiment of Fig. 3, the light-guiding earbud 30 is configured for optical coupling that is parallel to the light guide (i.e., cover 18). The optical detector 26 and optical emitter 24 are configured to detect and generate light substantially parallel to the light-guiding region 19 of the light guide 18. For example, the light guide 18 defines an axial direction A_1. The optical emitter 24 and optical detector 26 are each oriented such that their respective primary emitting and detecting planes P_1, P_2 are each facing a respective direction A_3, A_2 that is substantially parallel with direction A_1.

The light guiding region 19 of the light guide 18 in the illustrated embodiment of Fig. 3 is defined by cladding material 21 that helps confine light within the light guiding region 19. The cladding material 21 may be reflective material in some embodiments. In other embodiments, the cladding material may be optically transparent or mostly transparent with a lower index of refraction than the light transmissive material of the cover 18. The cladding 21 may be a layer of material applied to one or more portions of the inner and/or outer surfaces 18a, 18b of the light guide 18. In some embodiments, the outer surface 16a of the earbud housing 16 may serve as cladding that confines light within the light-guiding region 19. In some embodiments, the light transmissive material of the light guide 18 may be composed of a material having a higher index of refraction than the cladding material 21. In some embodiments, air may serve as a cladding layer.

In the embodiment of Fig. 4A, the light-guiding earbud 30 is configured for optical coupling that is substantially perpendicular to the light guide (i.e., cover 18). The optical detector 26 and optical emitter 24 are configured to detect and generate light substantially perpendicular to the light-guiding region 19 of the light guide 18. For example, the light guide 18 defines an axial direction A_1. The optical emitter 24 and optical detector 26 are each oriented such that their respective primary emitting and detecting planes P_1, P_2 are each facing a respective direction A_3, A_2 that is substantially perpendicular to direction A_1. The orientation of the optical emitter 24 and optical detector 26 in Fig. 4A may be convenient for manufacturing purposes, where side-emitting LEDs and side-detecting photodetectors can couple directly to the light-guiding region 19 for generating light 111 and detecting light 110. This may relax size

constraints for an earbud 30 because the dimensions of the light-guiding region 19 may be independent of the optical emitter 24 and optical detector 26.

Fig. 4B illustrates the light-guiding earbud 30 of Fig. 4A modified such that the earbud cover 18 and cladding material 21 are elongated to reach deeper within the ear canal C of a subject, and closer to the tympanic membrane, for example. In the illustrated embodiment of Fig. 4B, there are no apertures in the housing 16 or cover 18. Acoustic energy 44 from/to the speaker/microphone passes through the material of the cover 18 and housing 16. The illustrated elongated configuration serves as both an optical light-guiding region and an acoustic wave-guiding region.

Fig. 4C illustrates the light-guiding earbud 30 of Fig. 4A modified such that the earbud cover 18 and cladding material 21 are elongated to reach deeper within the ear canal C of a subject, and closer to the tympanic membrane, for example. In the illustrated embodiment of Fig. 4C, apertures 34a, 34b in the housing 16 and cover 18 are provided. As such, the optical light-guiding region 19 and the acoustic wave-guiding region 54 are isolated from each other. The light-guiding region 19 may be a light transmissive material, such as a dielectric material, and the acoustic wave-guiding region 54 may be air or another material, and the separation between these regions may be defined by at least part of the cladding material 21. Embodiments of the present invention may include multiple openings 34a, 34b in the housing 16 and cover 18. The separation between the light-guiding region 19 and the acoustic wave-guiding region 54 may be defined by other structures composed of a variety of possible materials. Specific examples of these materials include plastic molding, metals, polymeric structures, composite structures, or the like.

Fig. 4D illustrates the light-guiding earbud 30 of Fig. 4A modified such that the earbud cover 18 and cladding material 21 are elongated to reach deeper within the ear canal C of a subject, and closer to the tympanic membrane, for example. In the illustrated embodiment of Fig. 4D, the area within the housing 16 may be air, silicone, plastic, or any material capable of passing sound. As such, at opening 34b, an interface exists between the material of the light-guiding region 19 and the material within the housing 16. In some embodiments, the light-guiding region 19 and the region within the housing 16 may both be air. In other embodiments, the light-guiding region 19 and the

region within the housing 16 may be formed from the same or different materials. In some embodiments, the region within the housing 16 may be formed from an optical wave guiding material identical or similar to the material in the light-guiding region 19.

In the embodiments of Figs. 4B-4D, the optical energy 110 coming from the ear may include optical wavelengths, such as IR wavelengths, emitting from the tympanic membrane due to black body radiation. If the optical detector 26 is configured to measure this black body radiation, then the earbud can be used to measure tympanic temperature, blood analyte levels, neurological, electrical activity, or metabolic activity of the earbud wearer.

Referring to Fig. 5, a light-guiding earbud 30 is configured for optical coupling that is parallel to the light guide (i.e., cover 18) as in the embodiment of Fig. 3. However, the embodiment of Fig. 5 does not include a separate earbud housing. Instead, the light guide 18 serves the function of the earbud housing. In addition, the light guide 18 includes multiple windows 18w formed in the cladding material 21 on the outer surface 18a of the cover and through which light 111 emitted by the light emitter 24 passes and multiple windows 18w through which scattered light 110 passes into the light guide 18 to be directed to the light detector 26. These openings 18w may extend circumferentially around the light guide 18 or may partially extend circumferentially around portions of the light guide 18. In some embodiments of this invention, the earbud housing and light guide 18 may be separated, as shown in other figures.

In addition, the illustrated light guide 18 of Fig. 5 is surrounded by a layer 29 of light transmissive material. One or more lenses 29L are formed in this layer 29 and are in optical communication with respective windows 18w in the light guide 18. In the illustrated embodiment, a lens 29L is in optical communication with a respective window 18w through which emitted light 111 passes, and a respective window 18w through which scattered light 110 passes. Lenses 29L are configured to focus inspection light 111 onto a particular region of the ear. Lenses 29L are configured to help collect scattered light 110 and direct the scattered light 110 into the light guiding region 19. In some embodiments, these lenses 29L may be a molded part of the light guide 18. The illustrated location of lenses 29L in Fig. 5 is non-limiting, and the lenses 29L may

be located wherever optical coupling between the earbud and ear is desired. Though convex lens embodiments are shown in Fig. 5, this is not meant to limit embodiments of the present invention. Depending on the desired optical coupling and configuration of the earbud against the ear, a variety of lens types and shapes may be useful, such as convex, positive or negative meniscus, planoconvex, planoconcave, biconvex, biconcave, converging, diverging, and the like.

Referring now to Fig. 6, a light guiding earbud 30, according to some embodiments of the present invention, includes a base 50, an earbud housing 16 extending outwardly from the base 50 that is configured to be positioned within an ear E of a subject, and a cover 18 of light transmissive material surrounding the earbud housing 16 that forms a light-guiding region 19. The earbud housing 16 is in acoustical communication with a speaker 22 and includes at least one aperture 34a through which sound from the speaker 22 can pass. The earbud housing 16 encloses the speaker 22, an optical emitter 24 and an optical detector 26 as illustrated. An additional light detector 26 is located on the base 50 but is not surrounded by the earbud housing 16.

The earbud housing 16 is formed of a cladding material. The cladding material may be reflective material in some embodiments. In other embodiments, the cladding material may be optically transparent or mostly transparent with a lower index of refraction than the light transmissive material of the cover 18. In some embodiments, the earbud housing 16 may be replaced by air, such that the cladding region is air. Air may have a smaller index of refraction than that of the cover 18, supporting light transmission along the cover 18. In other embodiments, a cladding region exists between the earbud housing 16 and the light-guiding region 19. In another embodiment, a cladding region exists covering the outside of light-guiding region 19, with the exception of regions surrounding the lens regions 18L.

A plurality of windows 16w are formed in the earbud housing 16 at selected locations to permit light emitted by the light emitter 24 to pass therethrough. In some embodiments, the earbud housing 16 may have translucent or transparent material that serves the function of one or more windows 16w. The cover 18 includes a plurality of lenses 18L that are in optical communication with respective windows 16w in the earbud housing 16. These

lenses 18L are configured to focus light 111 passing through a respective window 16w towards a particular region of the ear of a subject, and to help collect scattered light 110 and direct the scattered light 110 into the earbud housing 16 towards the light detector 26.

The earbud 30 of Fig. 6, via the locations of windows 16w, produces isotropic optical coupling, such that the light generated by the optical emitter 24 is roughly identical in all directions with respect to the earbud housing 16. The inspection light 111 generated by the optical emitter 24 passes isotropically into the light guiding region 19 through the windows 16w.

A benefit of light guiding earbud 30 of Fig. 6 is that manufacturing may not require alignment of the light-guiding region 19 with respect to the optical emitter 24 and detector 26. This may be in part because the optical energy density generated/detected by the optical emitter/detector may be the same, or relatively uniform, within the earbud housing 16 regardless of alignment of the light guide 18 with respect to the earbud housing 16 or regardless of alignment between the optical emitters/detectors and the earbud housing 16. This effect may be similar to that observed in "integrating spheres" commonly used for quantifying the lumen output of an optical source. Namely, because the light from the optical emitter 24 may be substantially isotropic and not focused, there is less restriction on the alignment of the earbud housing and earbud cover with respect to the optical emitter 24 or optical detector 26.

Referring now to Figs. 7A-7B, a light guiding earbud 30, according to some embodiments of the present invention, includes a base 50, and an earbud housing 16 extending outwardly from the base 50 that is configured to be positioned within an ear E of a subject. The earbud housing 16 is formed from translucent material such that light can pass therethrough and forms a light-guiding region 19. The earbud housing 16 is in acoustical communication with a speaker 22 and includes at least one aperture 34a through which sound from the speaker 22 can pass. A pair of optical detectors 26 are secured to the base 50 but are not surrounded by the earbud housing 16, as illustrated.

The earbud housing 16 includes a flexible optical emitter 24 integrally formed within the housing 16, as illustrated. The optical emitter 24 is flexible such that it may be positioned around the earbud in an earbud form-factor. The flexible optical emitter 24 is configured to be conformable to an

earbud shape and configuration. The flexible optical emitter 24 may be in, near, or part of the earbud housing 16, cladding material 21, or housing 16. In some embodiments, the flexible optical emitter 24 may be part of a flexible optical circuit inserted into an earbud 30.

The optical detectors 26 positioned outside the earbud housing 16 of the earbud 30 of Figs. 7A-7B collect scattered light from an ear originating from inspection light 111 generated by the flexible optical emitter 24. The flexible optical emitter 24 may be mounted to the earbud base 50 through one or more electrical connectors 24a. In some embodiments, these may be soldered, wired, or detachable connectors. In some embodiments, the flexible optical emitter 24 may include a flexible optical detector. In some embodiments, the flexible optical emitter 24 may be part of a flexible optical circuit comprising the form-factor of 24 shown in Figs. 7A-7B, where the flexible optical circuit may include one or more optical emitters and detectors as well as amplifiers, microprocessors, wireless circuitry, and signal conditioning electronics. In some embodiments, the flexible optical circuit may include a complete chipset for physiological and environmental detection and for wired/wireless transfer of data to a remote location. For example, these flexible devices may include an organic LED (OLED) and an organic optical detector circuit. This embodiment may be useful for generating a diffuse light beam towards the ear region and for detecting a diffuse optical scatter response from the ear region. In some embodiments, the emitter and detector on the flexible optical emitter 24 may be a traditional light-emitting diode (LED) and photodetector (PD) integrated onto a flexible printed circuit board. In other embodiments, transparent solid state optical emitters, detectors, or switches may be used. For example, an electrically controlled liquid crystal matrix may be embedded within an earbud, covering the flexible optical emitter 24. This may allow localized control of light flow to selected areas from/to the earbud going towards/away-from the ear. Additionally, this may allow localized control of light wavelength to selected areas.

Referring now to Figs. 8A-8B, a light guiding earbud 30, according to some embodiments of the present invention, includes a base 50, an earbud housing 16 extending outwardly from the base 50 that is configured to be positioned within an ear of a subject, and a cover 18 that surrounds the earbud housing 16. The earbud housing 16 is in acoustical communication with a

speaker 22 and includes at least one aperture 34a through which sound from the speaker 22 can pass. The cover 18 includes at least one aperture 34b through which sound from the speaker 22 can pass. The cover 18 includes a cladding material 21 on the outer surface 18a thereof, except at end portion 18f, as illustrated. In the illustrated embodiment, there is no cladding material on the cover inner surface 18b. The housing 16 is in contact with the cover inner surface 18b and serves as a cladding layer to define the light guiding region 19. The cover 18 with the illustrated cladding material 18c serves as a light guide that delivers light from the optical emitters 24 into an ear canal of a subject through cover end portion 18f. The cover 18 also collects light through end portion 18f and delivers the collected light to the optical detectors 26. Various configurations and arrangements of optical emitters and detectors may be utilized in accordance with embodiments of the present invention.

In the illustrated embodiment of Figs. 8A-8B, to reduce the risk of the inspection light 111 interrogating and saturating the optical detectors 26, a bottom portion 16a of the earbud housing 16 includes a light blocking region that blocks light from passing therethrough. This light blocking region 16a may be a black-painted region, an optically opaque region, or a material or structure that blocks light transmission. The illustrated configuration of the earbud housing 16 and bottom portion 16a may help confine inspection light 111 generated by the optical emitters 24 within the light-guiding layer (i.e., 19), guiding this light towards the ear region through the end portion 18f of the earbud 30.

In some embodiments, as illustrated in Fig. 8C, the earbud housing 16 may be at least partially reflective to scatter light within the cavity defined by the earbud housing 16. In such case, the optical energy 111 may exit the earbud 30 through apertures 34a, 34b in the housing 16 and cover 18. An advantage of this configuration is that light 111 can be focused on a particular region of the ear where a particular physiological activity may be located. Also, this configuration may reduce unwanted optical signals from regions that may not be relevant to the physiological activity of interest. Although Fig. 8C shows the apertures 34a, 34b positioned toward the tympanic membrane, the apertures 34a, 34b may be located at one or more other locations about the earbud 30. For example, an aperture may be formed in the housing 16 and cover 18 at the location where the earbud 30 contacts the antitragus of an ear to allow optical energy 111 to

interrogate the antitragus region of the ear.

In some embodiments, as illustrated in Fig. 8D, the earbud housing 16 may contain a material that reflects one or more wavelengths of light and transmits one or more wavelengths of light. For example, the earbud housing 16 may be comprised of a polymer, plastic, glass, composite material, or resin that reflects visible wavelengths and transmits IR wavelengths. Exemplary materials include color absorbing materials, such as organic dyes, found in photographic film. Alternatively, the earbud housing 16 may include an optical filter region, such as a Bragg filter or other optical filter layer deposited on one or more sides of the housing region. If an optical detector 26' is configured to measure visible wavelengths only, then the optical energy detected by optical detector 26' may consist primarily of optical energy scattered from the earbud housing 16, and the optical energy detected by the optical detectors 26 may consist of optical energy scattered from the ear region. This configuration may be useful because the signal from the optical detector 26' may represent motion noise which may be removed from the signal derived from the optical detectors 26, which may contain physiological information and motion noise.

Referring now to Figs. 9A-9B, a light guiding earbud 30, according to some embodiments of the present invention, includes a base 50, an earbud housing 16 extending outwardly from the base 50 that is configured to be positioned within an ear of a subject, and a cover 18 surrounding the earbud housing 16. The earbud housing 16 is in acoustical communication with a speaker 22 and includes at least one aperture 34a through which sound from the speaker 22 can pass. The cover 18 includes at least one aperture 34b through which sound from the speaker 22 can pass. A pair of optical emitters 24 are secured to the base 50 and are surrounded by the earbud housing 16, as illustrated. An optical detector 26 is secured to the base 50 and is not surrounded by the earbud housing 16, as illustrated. The cover 18 serves as a light guide that delivers light from the optical emitters 24 into an ear canal of a subject.

The light-guiding region 19 of the cover 18 is designed to diffuse light and/or to generate luminescence. In this embodiment, the light-guiding region 19 includes at least one optical scatter or luminescence region. The optical scatter or luminescence region may be located anywhere within the

earbud in the optical path of the optical emitters 24, but preferably within or about the cladding layer itself. When inspection light 111 generated by the optical emitters 24 is scattered or by an optical scatter region, this light may form a more diffuse optical beam 111a that is more uniform across the earbud 30 than the inspection light 111 generated by the optical emitters 24. This diffused beam, having an intensity distribution being less sensitive to motion of the ear, may be useful in alleviating motion artifacts in the scattered light coming from the ear, such that the scattered light coming from the ear, measured by the optical detector 26, is more indicative of blood flow changes within blood vessels and less indicative of mouth movements and body motion. The optical scatter region within the light-guiding region 19 may be at least partially comprised of impurities or morphological differences within the light-guiding region. An example of such impurities may include point defects, volume defects, native defects, metallics, polymers, microspheres, phosphors, luminescent particles, air pockets, particles, particulate matter, and the like. An example of morphological differences may include density variations, roughness, air pockets, stoichiometry variations, and the like. As a specific example, the light-guiding region 19 may comprise a transparent material, such as glass, a polymer, or silicone, and a luminescent impurity, such as a phosphor or luminescent polymer or molecule, may be integrated within the light-guiding region. This configuration may generate luminescence within the light-guiding region 19 in response to optical excitation from the optical emitters 24. In other embodiments, nanoscale fluctuations or impurities may be used to diffuse or manipulate light through the earbud. Examples of nanoscale fluctuations or impurities may include quantum dots, rods, wires, doughnuts, or the like.

Fig. 9C illustrates an exemplary homogeneous distribution of luminescent particles 44, such as phosphors, embedded within the earbud cover 18, according to some embodiments of the present invention. Figs. 9D-9E illustrate an exemplary distribution of luminescent particles 44, such as phosphors, where the particles are distributed near one or more surfaces of the earbud cover 18, according to some embodiments of the present invention.

In another embodiment, an optical scatter or luminescent region may be at least partially located in a separate region from the light-guiding region 19, such as a coating, that may be in physical contact with the light-guiding

region 19.

In another embodiment, the optical scatter region or luminescent region may include multiple layers of light-guiding material having at least one dissimilar optical property, such as a dissimilar index of refraction, transparency, reflectivity, or the like. In another embodiment, the optical scatter region may include one or more patterned regions having at least one dissimilar optical property.

In another embodiment, the optical scatter or luminescent region may be distributed at select locations throughout the earbud.

Fig. 10 illustrates relevant anatomy of a human ear E. Blood vessels are located across the ear, but it has been discovered that photoplethysmography (PPG) signals are the strongest near the antitragus, tragus, lobule, and portions of the acoustic meatus, and the ear canal. The antitragus is a particularly attractive location for photoplethysmography because a strong PPG signal can be derived with minimal motion artifacts associated with running and mouth motion.

Referring now to Figs. 11A-11B, a light guiding earbud 30, according to some embodiments of the present invention, includes a base 50, an earbud housing 16 extending outwardly from the base 50 that is configured to be positioned within an ear of a subject, and a cover 18 surrounding the earbud housing 16. The earbud housing 16 is in acoustical communication with a speaker 22 and includes at least one aperture 34a through which sound from the speaker 22 can pass. The cover 18 includes at least one aperture 34b through which sound from the speaker 22 can pass. The cover 18 serves as a light guide for directing light into an ear of a subject and defines a light-guiding region 19. The illustrated earbud 30 is configured to focus light towards the antitragus of the ear of a human. In the illustrated embodiment, there is no cladding material on the outer surface 18a or inner surface 18b of the cover 18. Air serves as a cladding layer at the outer surface 18a and the housing 16 serves as a cladding layer at the inner surface 18b. Air may serve as a sufficient cladding layer due to the index of refraction difference between air and the light guiding layer. Namely, the index of refraction of the light-guiding layer 19 may be more than that of air.

A sensor module 70 is located near the earbud periphery, as illustrated. This sensor module 70 is shown in more detail in Figs. 12a-12B, and

is described below. Three benefits of locating the sensor module 70 near the periphery of the light-guiding earbud 30 are: 1) PPG signals near the antitragus are less corrupted by motion artifacts than are PPG signals in other blood-vessel-rich regions of the ear; 2) the sensor module 70 may be designed somewhat independently of the earbud 30, liberating earbud comfort maximization from PPG signal maximization; and 3) because design constraints may be liberated, sensors need not be located in the acoustic cavity (i.e., within the earbud housing 16), allowing sound to pass through the acoustic orifices 34a, 34b with minimal interference. In this embodiment, it may be beneficial to incorporate lenses within the cover 18, similar to the lenses 18L of Fig. 6. It may be beneficial to extend the light-guiding region 19 of the cover 18 near the location where the earbud 30 rests near the antitragus. This light-guide extension 19a serves as an additional light-coupling region and may improve optical coupling from the light-guiding region 19 to an ear region and/or improve optical coupling from an ear region to the light-guiding region 19, including the antitragus and portions of the acoustic meatus. This is because this extended light-guiding region 19a may provide skin contact between the light guiding layer 19 and the skin, providing better optomechanical stability and optical coupling. In this embodiment, light may couple into the extended light-guiding region 19a, from an optical emitter 24, and into the ear region. Similarly, light may couple from the ear region, into the extended light-guiding region 19a, and to the optical detector 26. This extended light-guiding region 19a may appear as a bulb or lens near the bottom of the earbud cover 18.

Figs. 12A-12B illustrate respective opposite sides of a sensor module 70 that may be located near the periphery of an earbud 30, for example as illustrated in Figs. 11A-11B, according to some embodiments of the present invention. Sensor module 70 may include a number of electronic components capable of converting various forms of energy into an electrical signal and digitizing the signal. For example, the sensor module 70 may include light-emitting diodes, optical sensors, accelerometers, capacitive sensors, inertial sensors, mechanical sensors, electromagnetic sensors, thermal sensors, nuclear radiation sensors, biological sensors, and the like. In some embodiments, the optical emitters of this invention may be a combination of side-emitting, edge-emitting, or surface-emitting light-emitting diodes (LEDs) or laser diodes (LDs).

In the illustrated embodiment of Figs. 12A-12B, the sensor module 70 includes two sets of optical emitters 24a, 24b. The first set of optical emitters 24a may be side-emitters (or edge-emitters) that are located at the top of the module 70 and direct light towards the earbud tip (e.g., cover end portion 18f, Fig. 8A) and towards the acoustic meatus and/or ear canal of the ear. The second set of optical emitters 24b may be located near the middle of the module 70 and may direct light in a beam that is largely perpendicular to that of the side-emitters 24a. In this particular embodiment, a single optical emitter 24b is shown mounted on a circuit board 70c such that this optical emitter 24b directs light towards the antitragus, which is located largely perpendicular to the acoustic meatus.

The optical energy generated by these optical emitters 24a, 24b may be scattered by blood vessels in the ear. This scattered light may be at least partially captured by the optical detectors 26. This light may be digitized by an optical detector 26 itself or with other circuitry on the sensor module circuit board 70c. The light-guiding design of the aforementioned light-guiding earbuds 30 may direct light towards each of these detectors 26. For example, this may be accomplished via the light-guiding earbud 30, wherein a lens (e.g., 18L, Fig. 6) facilitates inspection light coupling from the optical emitters 24 into the ear region and facilitates scattered light coupling to the optical detectors 26 from the ear region. Additional sensor components 27a, 27b may be used to measure an orthogonal energy component, facilitate sensor analysis, and thus help generate physiological assessments. For example, sensor components 27a, 27b may be thermal sensors for measuring the temperature of the inner ear (using the thermal sensors 27a facing the ear region) with respect to the outer ear (using the thermal sensor 27b facing away from the ear region). By subtracting the two measured digitized temperatures from these two sensors 27a, 27b, an indication of heat flow from the ear can be generated. This temperature differential may be mathematically related to metabolic rate. For example, this temperature differential may be directly proportional metabolic rate. These temperature sensors may include thermistors, thermopiles, thermocouples, solid state sensors, or the like. They may be designed to measure thermal conduction, convection, radiation, or a combination of these temperature components.

The earbud-facing side (Fig. 12B) of the sensor module 70 may

include sensors that do not need to be located on the antitragus-facing side of the sensor module. For example, one or more inertial sensors 27c may be located on the earbud-facing side (Fig. 12B) of the sensor module 70. In a particular embodiment, the inertial sensor 27c may be a 3-axis accelerometer, and because this sensor does not need to optically couple with the ear region, a better use of sensor real estate may be to locate this sensor on the earbud-facing side of the sensor module 70. Additional optical emitters 24a, 24b may be located on the earbud-facing side to facilitate an optical noise reference. Namely, as the person wearing the earbud module 30 moves around, the interrogation light generated by the optical emitters 24a, 24b may be scattered off the earbud and be detected by optical detectors 27d. This scattered light intensity, phase, and/or frequency due to body motion may be proportional to the motion-related component of the scattered light intensity from the ear region. The motion-related component is the component due to the physical motion of the ear and not the component related to blood flow. Thus, the optical scatter signal collected by the detectors 27d may provide a suitable noise reference for an adaptive filter to remove motion artifacts from the scattered light from the ear region, generating an output signal that is primarily related to blood flow (which may be the desired signal). In the same token, the scattered light reaching the optical detectors 27d may be used to generate a measure of activity. The intensity, phase, and frequency of this scattered light may be related to physical activity. Sinusoidal variations of the heart rate waveform may be counted digitally, by identifying and counting crests and peaks in the waveform, to generate an effective step count. Embodiments of the present invention, however, are not limited to the illustrated location of components in the sensor module 70. Various types and orientations of components may be utilized without limitation.

Fig. 19 illustrates the optical interaction between the sensor module 70 of Figs. 12A-12B and the skin of a subject. The sensor module 70 is shown in a reflective pulse oximetry setup 80 where reflected wavelengths 110 are measured, as opposed to measuring transmitted wavelengths. The optical emitter and optical detector wavelengths for pulse oximetry and photoplethysmography may include ultraviolet, visible, and infrared wavelengths. In the illustrated embodiment, an optical source-detector assembly 71 is integrated into sensor module 70 to generate optical wavelengths 111 and

monitor the resulting scattered optical energy 110. The optical source-detector assembly 71 contains one or more optical sources emitting one or more optical wavelengths, as well as one or more optical detectors detecting one or more optical wavelengths.

The epidermis 90, dermis 91, and subcutaneous 92 layers of skin tissue are shown in Fig. 19 for reference. The scattered optical energy 110 may be modulated in intensity by changes in blood flow in the blood vessels, changes in physical motion of the body, respiration, heart rate, and other physiological changes. In some cases, the scattered optical energy may be luminescent energy from the skin, blood, blood analytes, drugs, or other materials in the body.

As previously described, the optical scatter signal collected by the detectors 27d may provide a suitable noise reference for an adaptive filter to remove motion artifacts from the scattered light from the ear region, generating an output signal that is primarily related to blood flow (which may be the desired signal). This is because light detected by these detectors would come from light that has not been scattered by a physiological region but rather light that has been scattered from a region of the associated earpiece that may move along with the ear. Thus, the scattered light reaching the optical detectors 27d may be used to generate a measure of activity.

Fig. 13 illustrates the basic configuration of an adaptive noise cancellation scheme 200 for extracting a physiological signal from noise. The two types of sensor inputs are represented by the terms "Channel A" and "Channel B". Channel A refers to inputs from sensors that collect physiological information plus noise information, and Channel B refers to inputs from sensors that collect primarily (or substantially) noise information. Channel B information is passed through an electronic filter 203 whose properties are updated adaptively and dynamically. The filter 203 properties are updated to minimize the difference between Channel A and the post-processed Channel B, denoted as B^. In this way, noise is removed from Channel A and Channel C contains predominantly physiological information from which parameters such as blood flow, heart rate, blood analyte levels, breathing rate or volume, blood oxygen levels, and the like may be calculated. It is important to note that the Channel A information can still be useful despite the presence of noise, and the noise information may still be

utilized for the computation of relevant parameters. For instance, the residual noise information in Channel A may be extracted by a parameter estimator 201 and the output in Channel D may be one or more activity assessments or the like. Similarly, the raw noise channel, Channel B, may be post-processed by a parameter estimator 205 to extract activity assessments for Channel E. Activity assessments may include exertion, activity level, distance traveled, speed, step count, pace, limb motion, poise, performance of an activity, mastication rate, intensity, or volume, and the like. The noise cancellation scheme 200 may be integrated into the firmware of a microprocessor or the like.

Although the embodiment of Fig. 13 for cancelling motion noise has been presented for an earbud configuration, this does not limit the invention to earbuds. An element of the adaptive noise cancellation scheme 200 for cancelling motion noise with an optical noise source may be that the optical detectors (such as 27d) are configured such that they do not receive scattered light from a physiological region while the detectors are simultaneously receiving scattered light from a region that is moving in synchronization with the physiological region. Even the slightest physiological signal existing in the optical noise reference of Channel B may prevent the adaptive filter from working properly such that the physiological signal may inadvertently be removed altogether by the filter 203. Furthermore, although the noise source Channel B is described as an optical noise source, other forms of energy may be used in this invention. Namely, any inertial sensor input may constitute the input for Channel B. More specifically, a sensor for measuring changes in capacitance along the earbud with respect to the ear may provide an inertial noise reference without also measuring physiological information. Similarly, an accelerometer may provide an inertial noise reference without also measuring physiological information. An inductive sensor may also provide an inertial noise reference without also measuring physiological information. For each noise source, a defining element may be that the noise source may be configured to measure physical motion only (or mostly) and not physiological information (such as blood flow, blood oxygen, blood pressure, and the like). The utility of an optical noise source is that because the optical signal Channel A and the optical noise Channel B have the same linearity response, the adaptive filter scheme 200 may be more effective than the case where the signal and noise channels operate via

different forms of sensed energy. For example, the response linearity characteristics of an accelerometer sensor in response to inertial changes may not be the same as the response linearity characteristics of an optical sensor.

The adaptive noise cancellation scheme 200 for cancelling motion noise with an optical source (specifically an infrared LED) has been demonstrated in the laboratory, with a human wearing a light-guiding earbud while resting, jogging, and running over a treadmill, and various data summaries 300a-300d are presented in Figs. 14A-14D. The data was recorded by a chip and memory card embedded in an earbud 30, having electrical connectivity with the sensor module 70 within the earbud 30. The raw signal in low motion 300a and raw signal in high motion 300c may be equated with the signal of Channel A of Fig. 13. Similarly, the "blocked channel" in low motion 300b and "blocked channel" in high motion 300d may be equated with Channel B of Fig. 13. In this experiment, the "block channel" consisted of an optical noise source, wherein the optical noise source included an optical emitter-detector module such as 70 of Figs. 12A-12B. However, instead of being exposed to the ear, the optical emitter-detector module was covered with a layer of clear silicone that was then covered by black tape to prevent light from the emitter (such as 24a and 24b) from reaching the ear. Thus, scatter from the black tape was scattered back to the emitter-detector module through the silicone and sensed as motion noise by the detectors (such as 26 and 27d). In a sense, for this configuration, the optical channel to the human ear is "blocked", hence the term "blocked channel". The purpose of the clear silicone below the black tape was to: 1) provide an unobstructed, transparent optical scatter path for the IR light and 2) provide motion sensitivity similar to that of human skin, as silicone has a vibration response that may be similar to that of human skin.

Figs. 14A-14D show that the raw signal in low motion 300a indicates blood flow pulses which can be translated as heart rate. This is because each blood flow pulse represents one heart beat. However, the raw signal in high motion 300c indicates measured mostly physical activity. This is evident by the fact that the high motion signal 300c matches the corresponding blocked channel signal 300d, and the blocked channel in high motion 300d was found to have a substantially identical beat profile with the measured steps/second of the runner.

Fig. 15 is a graph of processed physiological signal data from a headset having one or more light-guiding earbuds 30, according to some embodiments of the present invention. Specifically, Fig. 15 shows the analysis results 400 of the data summaries 300a-300d presented in Figs. 14A-14D of blood flow (y-axis) versus time (x-axis) following two data processing sequences to extract heart rate. One sequence incorporated the adaptive filtering process 200 of Fig. 13 as well as a beat finder processing step. The second sequence incorporated the beat finder processing step without the adaptive filtering process 200 of Fig. 13. The beat finder process counts each heart beat by monitoring the peaks and valleys of each pulse, such as the peaks and valleys shown in the graph 300a of Fig. 14A. As shown in Fig. 15, the beat finder was effective at measuring heart rate during resting and jogging. However, the beat finder alone was not sufficient for monitoring heart rate during running. This is because at high motion, the signal 300d (Fig. 14D) associated with footsteps is strong enough to overwhelm the smaller signal associated with heart rate, and so the motion-related contribution dominated the overall signal 300d. Thus, the beat finder cannot distinguish heart beats from footsteps. By employing the adaptive filtering process 200 (Fig. 13) before the beat finder process, the footstep motion artifacts during running were effectively removed from the sensor signal (Channel A of Fig. 13) such that the output signal (Channel C of Fig. 13) contained blood flow information with minimal motion artifacts. Thus, this output signal contained blood flow pulse signals that could then be "counted" by the beat finder to generate an accurate heart rate assessment.

In the specific analysis results 400 of Fig. 15, a beat finder was employed, following the adaptive filter process 200 of Fig. 13, to count heart beats. A more general method 500 for extracting physiological information from sensor signals in the midst of noise is illustrated in Fig. 16. The first block (block 510) represents the pre-adaptive signal conditioning stage. This process may utilize a combination of filters to remove frequency bands outside the range of interest. For example, a combination of band-pass, low-pass, and/or high-pass filters (such as digital filters) may be used. The second block (block 520) represents an adaptive filtering process such as the process 200 described in Fig. 13. This process may utilize the pre-conditioned signals from block 510 as inputs into an adaptive filter that reduces motion or environmental artifacts and

noise in the primary data channel. The third block (block 530) represents the parameter extraction stage. This process may utilize a combination of signal conditioning filters in addition to peak finding (such as beat finding) algorithms to calculate properties of interest (e.g. heart rate, blood flow, heart rate variability, respiration rate, blood gas/analyte level, and the like). The method 500 of Fig. 16 may be encoded in the firmware of a microprocessor (or similar electronics) to facilitate real-time processing of physiological information.

Fig. 17 is a block diagram that illustrates sensor signals being processed into a digital data string including activity data and physiological data using the method 500 of Fig. 16, according to some embodiments of the present invention. Optical detectors 26 and optical emitters 24 may include digitizing circuitry such that they may be connected serially to a digital bus 600. Data from the detectors 26 may be processed by a processor/multiplexer 602 to generate multiple data outputs 604 in a serial format at the output 606 of the processor 602. In some embodiments, the processing methods may involve one or more of the methods described in Figs. 13, 14A-14D, 15 and 16. The multiple data outputs 604 may be generated by the processor/multiplexer 602 by time division multiplexing or the like. The processor 602 may execute one or more serial processing methods, wherein the outputs of a plurality of processing steps may provide information that is fed into the multiplexed data outputs 604.

The multiplexed data outputs 604 may be a serial data string of activity and physiological information 700 (Fig. 18) parsed out specifically such that an application-specific interface (API) can utilize the data as required for a particular application. The applications may use this data to generate high-level assessments, such as overall fitness or overall health. Furthermore, the individual data elements of the data string can be used to facilitate better assessments of other individual data elements of the data string. As a specific example, the Blood Flow data string may contain information on the first and second derivatives of each blood pulse. This information may be processed from a PPG signal by running the adaptively filtered heart rate signal through a slope-finder algorithm (such as a differentiator circuit). In another example, the filtered PPG signal may be run through an integration circuit to estimate blood volume over each blood pulse. This information may then be used to assess blood pressure and blood oxygen levels more accurately than a direct measurement of

blood pressure or blood oxygen levels.

In some embodiments of the invention, new methods of generating physiological assessment algorithms are enabled. These new methods may be achieved by measuring each data output of the data output string 604 in real time while an earbud user is also wearing one or more benchmark sensors. Principal component analysis, multiple linear regression, or other statistical or machine learning techniques can then be used to generate statistical relationships between the data outputs 604 and high level assessments measured simultaneously by the benchmark sensors. These benchmark sensors may measure aerobic fitness level, VO_2max, blood pressure, blood analyte levels, and the like. The relationships between the earbud sensor and benchmark sensor readings may be translated as algorithms embedded in the earbud, wherein each algorithm generates at least one assessment for the earbud user. In some cases, Bland-Altman plots of the earbud-derived assessment value versus the benchmark value may be used to judge the effectiveness of the algorithm, and this information may then feedback into improving the said earbud-derived assessment algorithm. Examples of these assessments may include aerobic fitness level, VO_2max, blood pressure, blood analyte levels (such as blood glucose, oxygen, carbon monoxide, etc.), and the like.

In some cases, it may be important to remove the effects of ambient optical noise from the physiological signal of a light-guiding earbud 30. In such cases, one or more optical detectors 26 may be configured to measure outdoor or ambient lighting, and this information may be fed back into the processor 602 (Fig. 17) to extract external optical noise from the physiological signal. For example, some optical detectors may be configured to measure light from the ear, whereas others may be configured to measure light from the ambient environment, such as sunlight, room light, headlights, or the like. This may be achieved by directing the optical detectors towards and away from the ear, respectively. In a specific example, the ambient light reaching the optical detectors 26 may generate an undesirable sinusoidal response on an optical detector that is configured to measure light from the ear. This undesirable sinusoidal noise response may be generated as an earbud user moves their head from side to side while running. Thus, Channel A of the adaptive filter 200

(Fig. 13) may include physiological information plus undesired ambient optical noise information. To remove this noise from the final output Channel C, the output of the optical detector configured to measure ambient optical noise may be an input (Channel B of Fig. 13) into the adaptive filter 200. In this way, ambient noise from Channel A may be removed to generate a mostly physiological signal in Channel C.

The optical detectors 26 and emitters 24 may be of multiple wavelengths, with the goal of providing specialized physiological information for each wavelength. Referring to Fig. 19, for example, violet or UV light may be used to measure motion-related aspects of the ear, as violet and UV light may not penetrate greatly through the skin of the ear. Green, red, and IR wavelengths may have deeper penetration and provide information on the blood vessels and blood analyte levels. Blue wavelengths may be particularly useful for gauging changes in the size of the blood vessels.

Embodiments of the present invention may be more generally applied to non-optical or mix-optical configurations. For example, one or more of the detectors 26 and emitters 24 may be mechanical, acoustical, electrical, gravimetric, or nuclear detectors and emitters, all providing physiological information to the processor 602 (Fig. 17). For example, an accelerometer or capacitor may be used as a detector 26 for the noise reference (Channel B) input of an adaptive filter running in real-time on the processor 602.

Referring to Fig. 20, a chipset 800 for use in light-guiding earbuds 30, according to some embodiments of the present invention, may include optical emitters, optical detectors, mechanical, acoustical, electrical, gravimetric, nuclear detectors, additional sensors, signal processing, power regulation, digital control, and input/output lines. The chipset 800 may include firmware for signal extraction and for generating physiological assessments from information derived from the sensors and noise sources. One benefit of the chipset configuration is that the chipset 800 may be fully or partially integrated and hence compact and scalable to a wide range of products. To be integrated with a light-guiding earbud 30, the chipset 800 may be aligned such that the sensor region has an exposed window to a subject's ear. For example, the chipset 800 may be attached to the earbud base 50 or an earbud sensor module 70 and aligned line-of-sight through an acoustic orifice of an earbud and/or through a

transparent end portion of an earbud 30 (e.g., through end portion 18f of the earbud 30 of Figs. 8A-8B or 18w of Figs. 4 & 5).

A specific embodiment of a chipset 800 for a stereo headset, according to some embodiments of the present invention, is illustrated in Fig. 21. This stereo chipset 800 may be integrated into an electronic module that may be attached to a printed circuit board. In another configuration, this stereo chipset 800 may be integrated into 3 modules, wherein the right and left earbud sensors comprise two separate modules, embedded in right and left earbuds respectively, and wherein the remaining circuit elements comprise the main module.

According to other embodiments of the present invention, monitoring devices with light-guiding regions may be configured to be attached to earlobes, fingers, toes, other digits, etc. For example, Figs. 22A-22B illustrate a monitoring device 70 that is configured to fit over a finger F, for example, as a finger ring, according to some embodiments of the present invention. The illustrated monitoring device 70 includes a generally circular band capable of encircling a finger F of a subject, with a cylindrical outer body portion 72 and a generally cylindrical inner body portion 74 secured together in concentric relationship. The outer body portion may be formed from virtually any type of material and may have an ornamental configuration. In some embodiments, the outer body portion 72 may include a flex circuit containing various electronic components, such as a microprocessor, D/A converter, power source, power regulator, and the like. However, in some embodiments, the outer body portion 72 may not be required and the circular band of the monitoring device 70 includes only the inner body portion 74 secured to the base 50 (described below).

A base 50 is secured to the inner and outer body portions 74, 72 of the illustrated embodiment and may be similar to the base 50 described above with respect to Figs. 3, 4A-4D, 5, 6, 7A-7B, 8A-8D, 9A-9B, and 11A-11B. The base 50 provides support for one or more sensors. In the illustrated embodiment, the base 50 supports an optical emitter 24, an optical detector 26, and an optical noise detector 26'.

The inner body portion 74 includes light transmissive material similar to that of the cover 18 described above with respect to Figs. 3, 4A-4D, 5,

6, 7A-7B, 8A-8D, 9A-9B, and 11A-11B. In some embodiments, the inner body portion 74 is formed from a soft, resilient material, such as silicone, which deforms when a finger of a subject is inserted therethrough. However, various types of light transmissive materials may be utilized, without limitation.

A layer of cladding material 21 is applied to (or near) the outer surface 74a of the inner body portion 74 and a layer of cladding material 21 is applied to (or near) the inner surface 74b of the inner body portion 74, as illustrated, to define a light-guiding region 19. As such, the inner body portion 74 serves as a light guide that delivers light from the optical emitter 24 to the finger F of a subject at one or more predetermined locations and that collects light from the finger F and delivers the collected light to the optical detectors 26, 26'. In some embodiments, the cladding material 21 may be embedded within the inner body portion 74 adjacent to the outer surface 74a and inner surface 74b. In some embodiments, the outer body portion 72 may serve as a cladding layer adjacent to the inner body portion outer surface 74a.

In the illustrated embodiment, windows 74w are formed in the cladding material 21 and serve as light-guiding interfaces to the finger F. There may be any number of these windows, as may be required for sufficient optical coupling, and the windows 74w may include lenses such as those described above (e.g., lens 18L illustrated in Fig. 6), to focus light emitted by the optical emitter 24 onto one or more portions of a finger F and/or to focus collected light on the light detectors 26, 26'. Similarly, the windows 74w may include optical filters to selectively pass one or more optical wavelengths and reflect and/or absorb other optical wavelengths.

In the illustrated embodiment, the light-guiding region 19 includes light blocking members 80 that isolate light emitter 24 and light detector 26 from each other. In some embodiments, only a single light blocking member 80 may be utilized. For example, a single light blocking member 80 may be positioned between the light emitter 24 and light detector 26. By adding an additional blocking member 80, as illustrated, the only light reaching the optical detector 26 may be light passing through at least one portion of the finger.

In some embodiments, multiple light emitters 24 may be utilized. For example, light emitters of different wavelengths may be utilized. In some embodiments, multiple light detectors may be utilized that are configured to

measure light at different wavelengths (e.g., light detectors 26 and 26' may be configured to measure light at different wavelengths). In this way, either optical detector may be configured to measure light mostly due to motion (such as finger motion) or to measure light mostly due to physiological processes and motion. For example, if the windows 74w incorporate IR-pass filters, visible light will not pass through the windows 74w and the light will be scattered to the photodetectors 26 and 26'. Or, if the two illustrated blocking regions 80 are in place, and if photodetector 26' is configured to measure only visible light and photodetector 26 is configured to measure only IR light, then only the photodetector 26' will detect scattered visible light. As this visible scattered light cannot reach the finger, the scatter intensity measured by optical detector 26' may be indicative of motion and not physiological activity.

Referring now to Fig. 23, a monitoring device 70', according to some embodiments of the present invention, may be configured to be attached to a body of a subject as a bandage or "band-aid". The illustrated monitoring device 70' includes an outer layer or body portion 72 and an inner layer or body portion 74 secured together, as illustrated. The outer body portion may be formed from virtually any type of material and may have an ornamental configuration. In some embodiments, the outer body portion 72 may include a flex circuit containing various electronic components, such as a microprocessor, D/A converter, power source, power regulator, and the like. However, in some embodiments, the outer body portion 72 may not be required and the monitoring device 70' includes only the inner body portion 74 secured to the base 50 (described below).

A base 50 is secured to the inner and outer body portions 74, 72 and may be similar to the base 50 described above with respect to Figs. 3, 4A-4D, 5, 6, 7A-7B, 8A-8D, 9A-9B, and 11A-11B. The base 50 provides support for one or more sensors. In the illustrated embodiment, the base 50 supports an optical emitter 24, an optical detector 26, and an optical noise detector 26'.

The inner body portion 74 is formed of light transmissive material similar to that of the cover 18 described above with respect to Figs. 3, 4A-4D, 5, 6, 7A-7B, 8A-8D, 9A-9B, and 11A-11B. In some embodiments, the inner body portion 74 is formed from a soft, resilient material, such as silicone, which deforms when the device is attached to the body of a subject. However, various

types of light transmissive materials may be utilized, without limitation.

A layer of cladding material 21 is applied to (or near) the outer surface 74a of the inner body portion 74 and a layer of cladding material 21 is applied to (or near) the inner surface 74b of the inner body portion 74, as illustrated, to define a light-guiding region 19. As such, the inner body portion 74 serves as a light guide that delivers light from the optical emitter 24 to the body of a subject at one or more predetermined locations and that collects light from the body and delivers the collected light to the optical detectors 26, 26'. In some embodiments, the cladding material 21 may be embedded within the inner body portion 74 adjacent to the outer surface 74a and inner surface 74b. In some embodiments, the outer body portion 72 may serve as a cladding layer adjacent to the inner body portion outer surface 74a.

In the illustrated embodiment, windows 74w are formed in the cladding material 21 and serve as light-guiding interfaces to the body of a subject. There may be any number of these windows, as may be required for sufficient optical coupling, and the windows 74w may include lenses such as those described above (e.g., lens 18L illustrated in Fig. 6), to focus light emitted by the optical emitter 24 onto one or more portions of the body of a subject and/or to focus collected light on the light detectors 26, 26'. Similarly, the windows 74w may include optical filters to selectively pass one or more optical wavelengths and reflect and/or absorb other optical wavelengths.

In the illustrated embodiment, the light-guiding region 19 includes a light blocking member 80 that isolates light emitter 24 and light detector 26 from each other. In some embodiments, multiple light emitters 24 may be utilized. For example, light emitters of different wavelengths may be utilized. In some embodiments, multiple light detectors may be utilized that are configured to measure light at different wavelengths (e.g., light detectors 26 and 26' may be configured to measure light at different wavelengths).

The illustrated monitoring device 70' may be removably attached to the body of a subject via adhesive on one or more portions of the device 70'. In some embodiments, adhesive may be on the inner body portion 74. In embodiments where the outer body portion is utilized, the adhesive may be on the outer body portion 74. In some embodiments, the illustrated device 70' may be removably attached to the body of a subject via tape or other known devices.

Referring now to Figs. 24A-24B, 25A-25B, and 34-40, headsets 10 that utilize one or more light guides 119 that are optically coupled with (i.e., in optical communication with) one or more optical emitters and/or optical detectors, according to various embodiments of the present invention, are illustrated. Each illustrated headset 10 includes a housing 14 that is configured to be supported within an ear of a person, and may also enclose and protect various electronic components mounted to a base 50 (Figs. 26-29) therewithin, as described above. For example, as described above, a base 50 may include any configuration and combination of one or more printed circuit boards, electrical connectors, processors, speakers, optical emitters and optical detectors. As such, each of the illustrated headsets 10 of Figs. 24A-24B, 25A-25B and 34-40 may include at least one optical emitter 24 and at least one optical detector 26 disposed within the housing 14. However, as described below, one or more optical emitters and/or one or more optical detectors may be remotely located from the housing 14. As described above, each optical detector 26 may be a photodiode, photodetector, phototransistor, thyristor, solid state device, optical chipset, or the like. The optical emitter 24 may be a light-emitting diode (LED), laser diode (LD), compact incandescent bulb, micro-plasma emitter, IR blackbody source, or the like.

In the embodiments of Figs. 24A-24B and 25A-25B, the distal end portion 119a of each of the light guides 119 extends outwardly from the housing 14. However, in other embodiments of the present invention, the distal end portion 119a of one or both light guides 119 may be substantially flush with the housing 14 or may even be recessed within the housing 14. The distal end 119a of each light guide 119 has an exposed end surface 119c that is configured to engage (or be positioned adjacent) a portion of an ear of a subject.

The exposed surface 119c is shown with a flat surface in Figs. 24A-24B and as a curve or rounded surface in Fig. 31 to demonstrate that light guides according to embodiments of the present invention may be shaped in a variety of ways to couple light to and from the body. For example, a rounded surface may improve light collection from a wider angle and a flat surface may narrow the field of view of the light guide. In some cases, a wider field of view may be important to measure more light from a broader range along the body, but in other cases, a narrower view may be important to focus the field of view

on a specific region of the body. For example, a light guide 119 with a flat-faced surface 119c within the earbud 10 of Figs. 24A-24B may focus the field of view to the region between the anti-tragus and concha of the ear. This region of the ear has been found by Applicants to contain a sufficient blood flow signal for photoplethysmography (PPG) while also being a region that is less prone to motion artifacts from chewing, talking, walking, running, or exercising. Less motion artifacts may result in less optical scatter from motion and hence result in less noise in the optical signal from the detector 26. A less noisy optical signal may result in a cleaner PPG signal upon analog or digital filtering of the optical signal. In contrast, a rounded distal end of a light guide as with the surface 119c of Figure 31 may capture a greater PPG signal but an even greater amount of motion artifact related optical scatter. Detailed novel methods of filtering optical signals from the optical detector 26 are disclosed in co-owned, co-pending U.S. Patent Application Publication No. 2012/0197093, and co-owned, co-pending PCT Application No. PCT/US12/48079, which are incorporated herein by reference in their entireties.

As used herein, the term "engage" is intended to mean that the distal end surface 119c may contact the skin of a person or may be closely adjacent the skin of a person, such as within a hundred microns to 3 or more millimeters away from the person, for example.

An opposite proximal end 119b of each light guide 119 is in optical communication with a respective optical emitter 24 and optical detector 26. As such, a respective light guide 119 is configured to deliver light from an optical emitter 24 into an ear region of the subject via the distal end exposed surface 119c, and a respective light guide 119 is configured to collect light from an ear region of the subject via the distal end exposed surface 119c and deliver collected light to the optical detector 26.

In the illustrated embodiment of Fig. 34, the distal ends 119a of each light guide 119 do not extend from the housing 14. Instead, the distal ends 119a of each light guide 119 are substantially flush with the housing 14. In some embodiments, one or both of the distal ends 119a of the light guides 119 of Fig. 34 may be recessed within the housing 14. A benefit of recessing the light guides may be to further narrow the field of view or to improve the comfort of the headset 10 worn within the ear, as may be desired for some applications.

In the illustrated embodiment of Figs. 24A-24B, the light guides 119 have an elongated, generally cylindrical configuration. In the illustrated embodiment of Figs. 25A-25B, the light guides 119 have a non-cylindrical, generally tapered configuration. In the embodiment of Fig. 34, the light guides 119 have a generally oval cross-sectional configuration. However, embodiments of the present invention are not limited to the illustrated configuration or shape of the light guides 119 of Figs. 24A-24B, 25A-25B and 34-40. Light guides 119 according to embodiments of the present invention may have various shapes, configurations, lengths, etc., without limitation. A benefit of a non-cylindrical or square light guide is that it may facilitate a more compact headset design.

Each light guide 119 in the various embodiments illustrated and described herein may be formed from various types of light transmissive material, typically with a refractive index of at least one (1). In some embodiments, a light guide 119 may be formed from an elastomeric light transmissive material. In other embodiments, a light guide 119 may be formed from a substantially rigid light transmissive material. In embodiments of the present invention where a headset or monitoring device includes a plurality of light guides 119, some of the light guides may be formed from an elastomeric light transmissive material, and some may be formed from a substantially rigid light transmissive material. Light guides according to some embodiments of the present invention may comprise one or more optical fibers. Exemplary light guide materials include, but are not limited to, polycarbonate, acrylic, silicone, and polyurethane.

Light guides 119, according to some embodiments of the present invention, may comprise optical filtering material, also. For example, a light-guide may comprise a material having an optically filtering dye or a material which inherently filters one or more wavelengths of light. For example, a light-absorptive dye, many of which are well-known in the art, may be integrated within or coated on top a polycarbonate or acrylic sheet. Similarly, a light-absorptive dye may be integrated within a resin which may then be molded into one or more light guides. A few non-limiting examples of an inherently filtering material includes sapphire, which absorbs some infrared (IR) wavelengths, or glass, which absorbs some ultraviolet (UV) wavelengths. However, various types of filtering material may be utilized, without limitation.

In some embodiments, a light guide 119 may be surrounded or partially surrounded by a cladding material 121 (Fig. 30) that is configured to block light from an external source from entering the light guide 119 and/or at least partially confine light within the light guide 119. The cladding material 121 may be a light blocking material and/or a light reflective material. For example, the cladding material 121 may be a dark (e.g., black, etc.) or silver (or other reflective color) coating, or a texturized light-scattering material on one or more portions of the surface of the light guide 119.

Figs. 26-29 illustrate various light guide configurations that may be utilized within headsets and wearable sensor modules (e.g., sensor modules that can be attached to earlobes, fingers, wrists, ankles, toes, other digits, other skin regions, etc.), according to some embodiments of the present invention. For example, when used in conjunction with Applicants' signal extraction technology, these sensor modules may function well when embedded within a wrist strap, wrist watch, ankle bracelet, armband, chest strap, and other form-factors that can engage the sensor module with the skin. Although the light guides 119 in Figs. 26, 27 and 29 are illustrated as having the same length, it is understood that embodiments of the present invention are not limited to light guides 119 having the same length.

In Fig. 26, an optical emitter 24 and optical detector 26 are attached to a base 50 and light blocking material 21 is positioned between the optical emitter 24 and detector 26 such that the optical emitter 24 and detector 26 are not in direct optical communication with each other. In some embodiments, the light blocking material 21 may completely block light from the optical emitter from directly reaching the optical detector 26. In other embodiments, the light blocking material 21 may partially block light from the optical emitter from directly reaching the optical detector 26.

As illustrated in Fig. 26, a respective light guide 119 is in optical communication with the optical emitter 24 and optical detector 26. However, in other embodiments, a plurality of light guides 119 may be in optical communication with the light emitter 24 and/or light detector 26. It should be noted that the free end 119c of the light guide 119 may branch out to two or more "legs" that may be used to couple with many different parts of the body, such as multiple parts of the ear. Monitoring multiple regions of the ear may be

beneficial as described in co-owned and copending U.S. Patent Application Publication No. 2010/0217098, which is incorporated herein by reference in its entirety.

As illustrated in Fig. 27, a headset or sensor module may include a plurality of optical emitters 24 and/or optical detectors 26 with a respective light guide in optical communication therewith. It should be noted that the light guides 119 may be used to couple with many different parts of the body, such as multiple parts of the ear.

As illustrated in Fig. 28, a single light guide 119 may be in optical communication with an optical emitter 24 and with an optical detector 26.

As illustrated in Fig. 29, optical coupling material 120 may be applied to one or both of the optical emitter 24 and optical detector 26 of a headset or sensor module. A light guide 119 is in optical communication with the optical emitter 24 and optical detector 26 via the optical coupling material 120. The optical coupling material 120 may comprise a material that effectively couples light from the optical emitter 24 to the light guide 119 or from the light guide 119 to the optical detector 26. Examples of suitable materials include, but are not limited to, glue, tape, resin, gel, filler material, molded material or the like. A few non-limiting examples of a molded material may include, but are not limited to, silicone, plastic, polymer, or polyurethane part that is form-fitted to matingly engage the light guide and the emitter and/or detector. A benefit of molded, form-fitted optical coupling is that it may be routinely attached/detached due to the non-permanent interface. This may be useful for the case where a light guide 119 may need to be routinely attached/detached from an emitter 24 and/or detector 26. Two attractive properties of suitable optical coupling materials may include: 1) a refractive index that matches or closely matches that of the emitter, detector, or light guide and 2) providing a solid interface between the coupled elements without an air gap in between.

In some embodiments of the present invention, such as illustrated in Figs. 24A-24B and 25A-25B, an optical emitter 24 and optical detector 26 are attached to or disposed within the housing 14. However, in other embodiments of the present invention, an optical emitter 24 and/or optical detector 26 can be located remotely from the housing 14. For example, as illustrated in Fig. 32, the optical emitter 24 and optical detector 26 may be located on a headband or other

structure that is a part of a headset. In the illustrated embodiment of Fig. 32, the headset 100 is a stereo headset having a pair of earbuds 30. An optical emitter 24 and optical detector 26 are located on the headband 100h of the headset 100. In some embodiments with wired headphones, the emitter and/or detector may be located on a "medallion" or a mobile device (such as a smartphone) itself, with the associated light guide(s) running in between the headphone and the medallion or mobile device.

A pair of elongated light guides 119, such as illustrated in Fig. 31, are in optical communication with the optical emitter 24 and optical detector 26 via proximal end portions 119b and extend from the optical emitter 24 and optical detector 26 to an earbud 30. The earbud 30 includes a pair of apertures 30a formed therethrough. Each light guide distal end is positioned within a respective earbud aperture 30a such an exposed end surface 119c thereof is configured to engage (or be positioned adjacent) a portion of an ear of a subject. As such, the light guide 119 in optical communication with the optical emitter 24 can deliver light from the optical emitter 24 into an ear region of the subject, and the light guide 119 in optical communication with the optical detector 26 can collect light from the ear region of the subject and deliver collected light to the optical detector 26. It should be noted that the distal free end surface 119c of the light guide 119 may comprise a variety of shapes, as discussed previously, more than exemplarily shown in Fig. 33.

The optical emitter 24 and optical detector 26 may be embedded within the headband 100h (also referred to as a "back band" as this may typically be worn behind the head), or may be located external to the headband 100h. In addition, the elongated light guides 119 in communication with the optical emitter 24 and optical detector 26 may be embedded within the headband 100h. However, in some embodiments of the present invention, the elongated light guides 119 may be external or at least partially external to the headband 110h.

Though many of the drawings herein show emitters and detectors in only one earbud, it should be understood that the emitters and detectors may be in multiple earbuds, left and right, for use in biometric monitoring. Certain benefits may be realized by incorporating light guides from the headband to both earbuds. For example, having emitters and detectors in multiple earbuds may enable the ability to measure the transit time between blood pulses on the right

and left sides of the head, and this measurement may be used to estimate the blood pressure of the person. For example, the blood moving from the carotid artery on the right of the head and moving to the left of the head may be modulated in part by the blood pressure, and thus by measuring the time difference between right and left blood pulses, and by integrating this measurement into a formula relating pulse transit time and blood pressure, potentially further including a relationship for arterial stiffness, a method of determining blood pressure may be implemented. Additionally, the difference between the intensity of the pulsatile blood flow signals, namely the difference in amplitude of the AC blood flow pulses, between the right and left sides of the head may be directly proportional to the blood pressure of the person wearing the headset. A suitable stereo headset configuration for providing this type of functionality may comprise a light guiding method as shown in Fig. 27, with a plurality of emitters and detectors.

Fig. 35 illustrates the headset 10 of Fig. 1 with light guides 119 in the earbud housing cover 18, according to some embodiments of the present invention. Each light guide 119 is configured to be in optical communication with a respective one of the optical emitter 24 and optical detectors 26. In this embodiment, the earbud housing cover 18 may be substantially opaque. As such, the only light transmissive paths are via the light guides 119. However, embodiments of the present invention represented by Fig. 35 do not require that the housing cover 18 be opaque.

Figs. 36-40 illustrate a headset 10 incorporating light guides 119 according to other embodiments of the present invention. The headset housing 14 includes an opaque front housing portion 14a (Fig. 40) and an opaque rear housing portion 14b (Fig. 40). A removable cover 18 is configured to be attached to and matingly engage the front housing portion 14a. The cover 18 can be provided in various sizes, each adapted to the shape and size of an ear of a subject. For example, covers 18 may come in large, medium, and small sizes, etc. The cover 18 may be formed from a soft or elastomeric material. Examples of suitable soft or elastomeric materials may include, but are not limited to, silicone, rubber, polymer-based materials, latex, lower durometer plastics, and the like.

The front housing portion 14 a includes a portion 14c that has a

pair of filter lenses 140 integral therewith. The cover 18 has a corresponding portion 18a that includes a pair of light guides 119 integral therewith, as illustrated. The light guides 119 are substantially flush with an end surface 18b of portion 18a in the illustrated embodiment. When the cover 18 is installed on the front housing portion 14a, the light guides 119 are in alignment (i.e., optical communication) with the filter lenses 140, as illustrated in Fig. 38.

The foregoing is illustrative of the present invention and is not to be construed as limiting thereof. Although a few exemplary embodiments of this invention have been described, those skilled in the art will readily appreciate that many modifications are possible in the exemplary embodiments without materially departing from the teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the claims. The invention is defined by the following claims, with equivalents of the claims to be included therein.

THAT WHICH IS CLAIMED IS:

1. A sensor module for detecting and/or measuring physiological information from a subject, the sensor module comprising:

a housing;

at least one optical emitter supported by the housing;

at least one optical detector supported by the housing;

a first light guide supported by the housing, wherein the first light guide is in optical communication with the at least one optical emitter, wherein the first light guide comprises a distal end, and wherein the first light guide is configured to deliver light from the at least one optical emitter into a body of the subject via the distal end thereof; and

a second light guide supported by the housing, wherein the second light guide is in optical communication with the at least one optical detector, wherein the second light guide comprises a distal end, and wherein the second light guide is configured to collect light from the body of the subject via the distal end thereof and deliver collected light to the at least one optical detector.

2. The sensor module of Claim 1, wherein the housing is configured to be integrated within an audio headset, a wrist strap, a wrist watch, an ankle bracelet, or an armband.

3. The sensor module of Claim 1, further comprising at least one motion sensor supported by the housing, wherein the at least one motion sensor is configured to sense motion information from the subject.

4. The sensor module of Claim 3, further comprising at least one processor supported by the housing, wherein the at least one processor is configured to remove motion artifacts from signals produced by the at least one optical detector in response to signals produced by the at least one motion sensor.

5. The sensor module of Claim 1, wherein the first light guide

comprises optical dye that is configured to filter one or more wavelengths of light guided by first light guide.

6. The sensor module of Claim 1, wherein the second light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by second light guide.

7. The sensor module of Claim 1, wherein at least one of the first and second light guides comprises elastomeric light transmissive material.

8. The sensor module of Claim 1, wherein at least one of the first and second light guides comprises substantially rigid light transmissive material.

9. The sensor module of Claim 1, wherein the at least one optical emitter comprises optical coupling material, and wherein the first light guide is in optical communication with the at least one optical emitter via the optical coupling material.

10. The sensor module of Claim 1, wherein the at least one optical detector comprises optical coupling material, and wherein the second light guide is in optical communication with the at least one optical detector via the optical coupling material.

11. The sensor module of Claim 3, further comprising at least one processor supported by the housing, wherein the at least one processor is configured to process signals produced by the at least one optical detector and signals produced by the at least one motion sensor to determine subject heart rate and respiration rate.

12. A sensor module for detecting and/or measuring physiological information from a subject, the sensor module, comprising:

a housing;

at least one optical emitter supported by the housing;

at least one optical detector supported by the housing;

a first light guide supported by the housing, wherein the first light guide is in optical communication with the at least one optical emitter, and wherein the first light guide is configured to deliver light from the at least one optical emitter into a body of the subject;

a second light guide supported by the housing, wherein the second light guide is in optical communication with the at least one optical detector, and wherein the second light guide is configured to collect light from the body of the subject;

a motion sensor supported by the housing, wherein the motion sensor is configured to sense motion information from the subject; and

a processor supported by the housing, wherein the processor is configured to remove motion artifacts from signals produced by the at least one optical detector in response to signals produced by the motion sensor, and wherein the processor is configured to process signals produced by the at least one optical detector to determine subject heart rate and respiration rate.

13. The sensor module of Claim 12, wherein the housing is configured to be integrated within an audio headset, a wrist strap, a wrist watch, an ankle bracelet, or an armband.

14. The sensor module of Claim 12, wherein the first light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by first light guide.

15. The sensor module of Claim 12, wherein the second light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by second light guide.

16. The sensor module of Claim 12, wherein at least one of the first and second light guides comprises elastomeric light transmissive material.

17. The sensor module of Claim 12, wherein at least one of the first and second light guides comprises substantially rigid light transmissive

material.

18. The sensor module of Claim 12, wherein the at least one optical emitter comprises optical coupling material, and wherein the first light guide is in optical communication with the at least one optical emitter via the optical coupling material.

19. The sensor module of Claim 12, wherein the at least one optical detector comprises optical coupling material, and wherein the second light guide is in optical communication with the at least one optical detector via the optical coupling material.

20. A sensor module for detecting and/or measuring physiological information from a subject, the sensor module, comprising:

a housing;

an optical emitter supported by the housing;

an optical detector supported by the housing;

a first light guide supported by the housing, wherein the first light guide is in optical communication with the optical emitter, wherein the first light guide comprises a distal free end, and wherein the first light guide is configured to deliver light from the optical emitter into a body of the subject via the distal end thereof; and

a second light guide supported by the housing, wherein the second light guide is in optical communication with the optical detector, wherein the second light guide comprises a distal free end, and wherein the second light guide is configured to collect light from the body of the subject via the distal end thereof and deliver collected light to the optical detector,

wherein the distal free ends of the first and second light guides are in adjacent, spaced-apart relationship.

ABSTRACT OF THE DISCLOSURE

A monitoring device configured to be attached to the ear of a person includes a base, an earbud housing extending outwardly from the base that is configured to be positioned within an ear of a subject, and a cover surrounding the earbud housing. The base includes a speaker, an optical emitter, and an optical detector. The cover includes light transmissive material that is in optical communication with the optical emitter and the optical detector and serves as a light guide to deliver light from the optical emitter into the ear canal of the subject wearing the device at one or more predetermined locations and to collect light external to the earbud housing and deliver the collected light to the optical detector.

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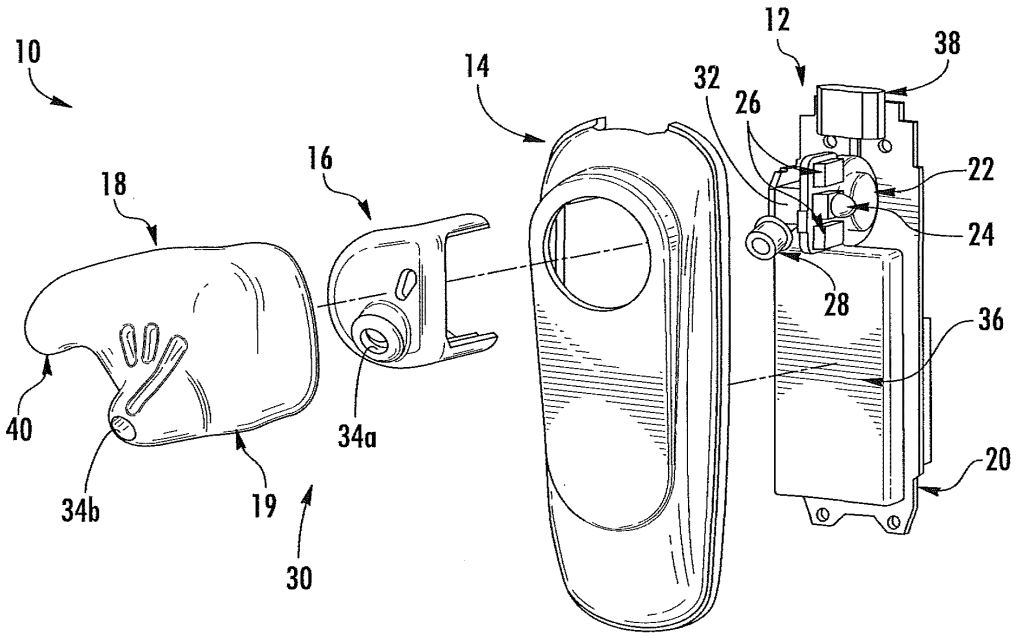


FIG. 1

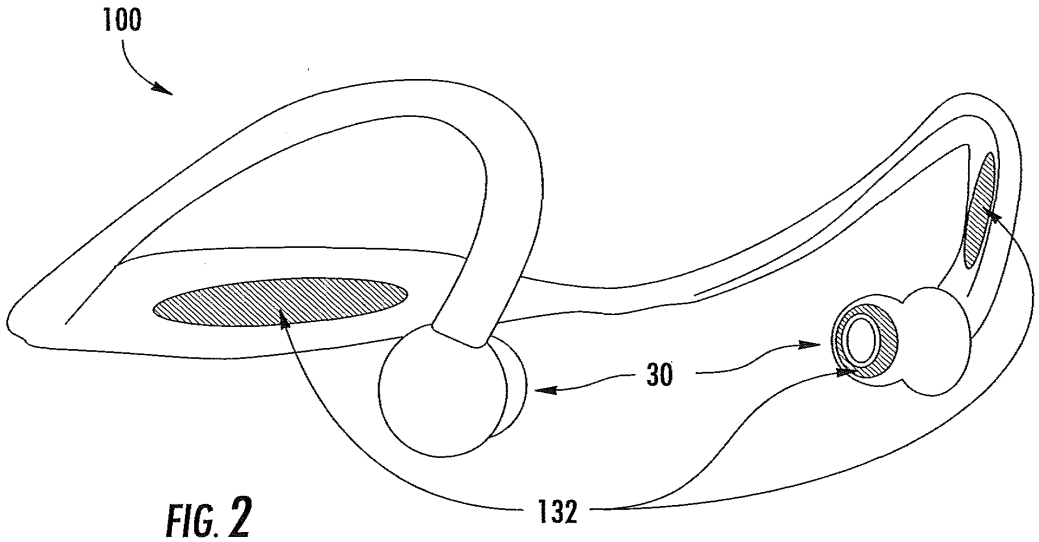


FIG. 2

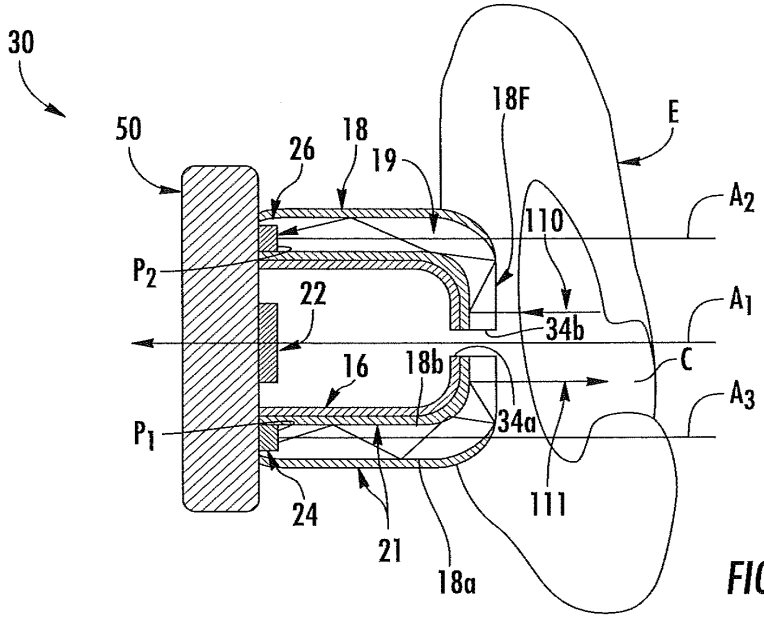


FIG. 3

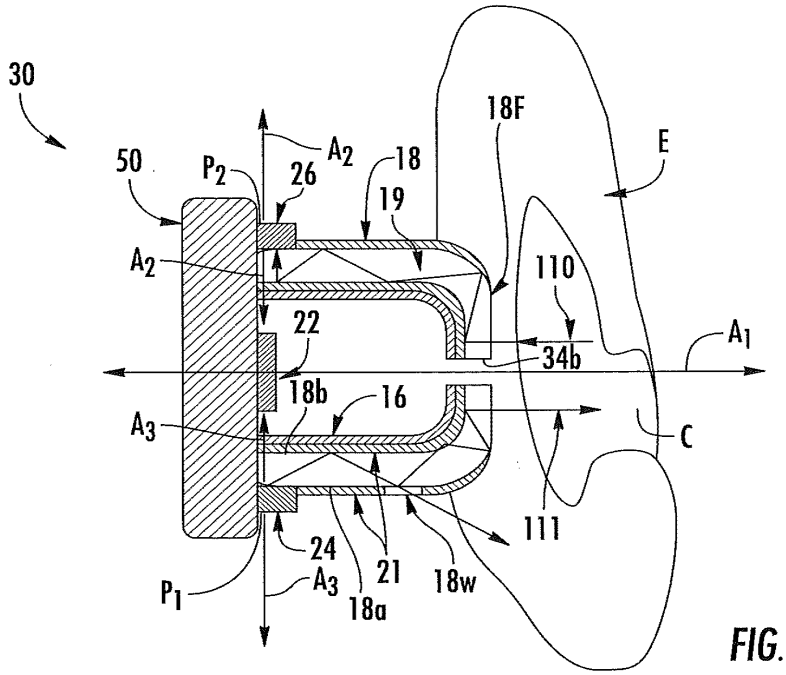


FIG. 4A

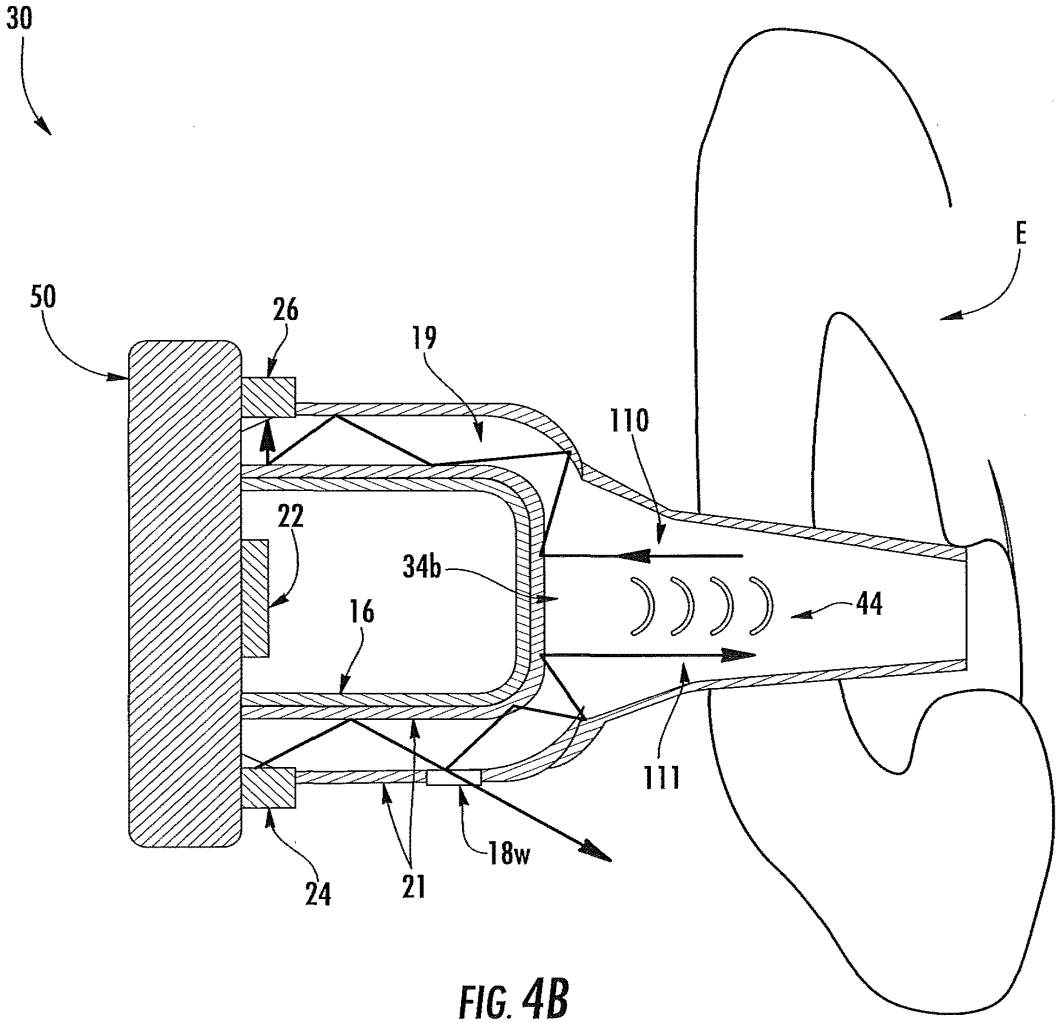


FIG. 4B

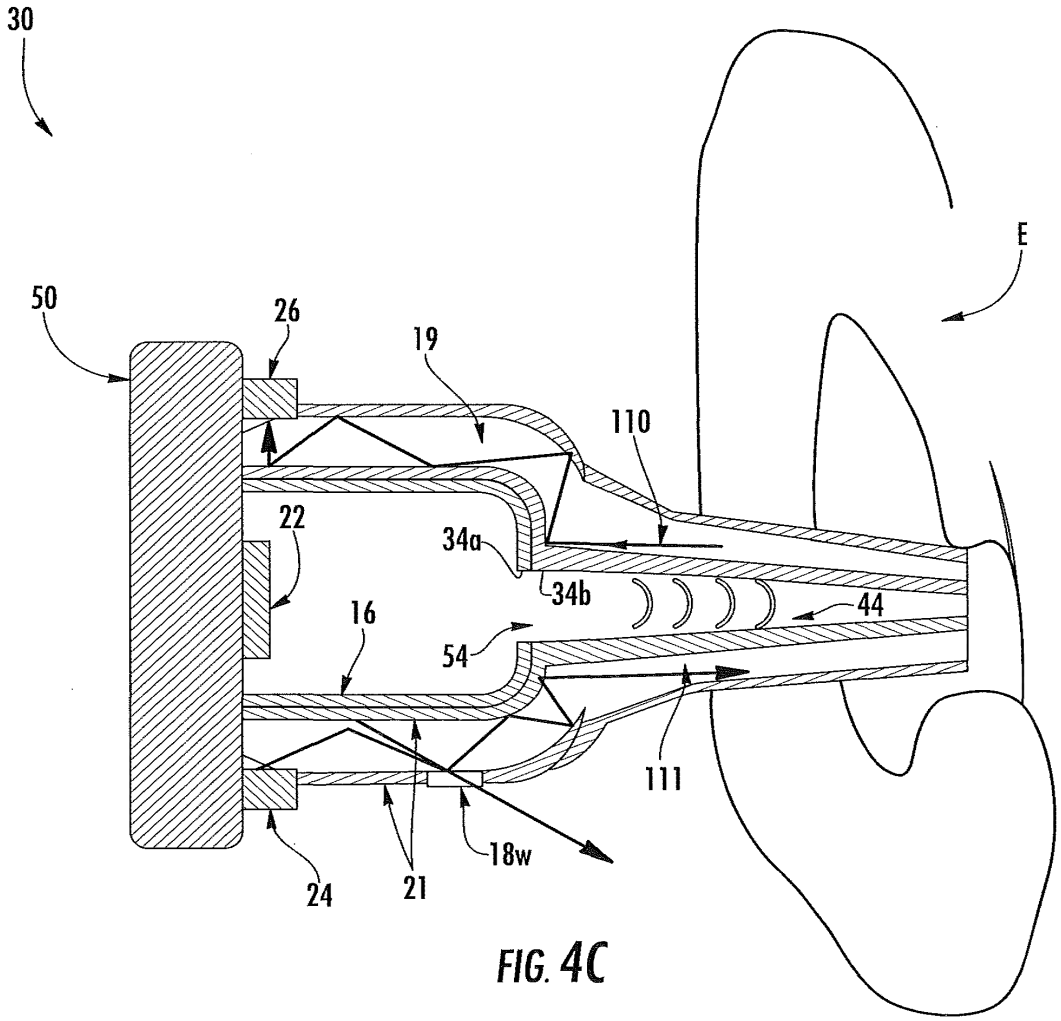


FIG. 4C

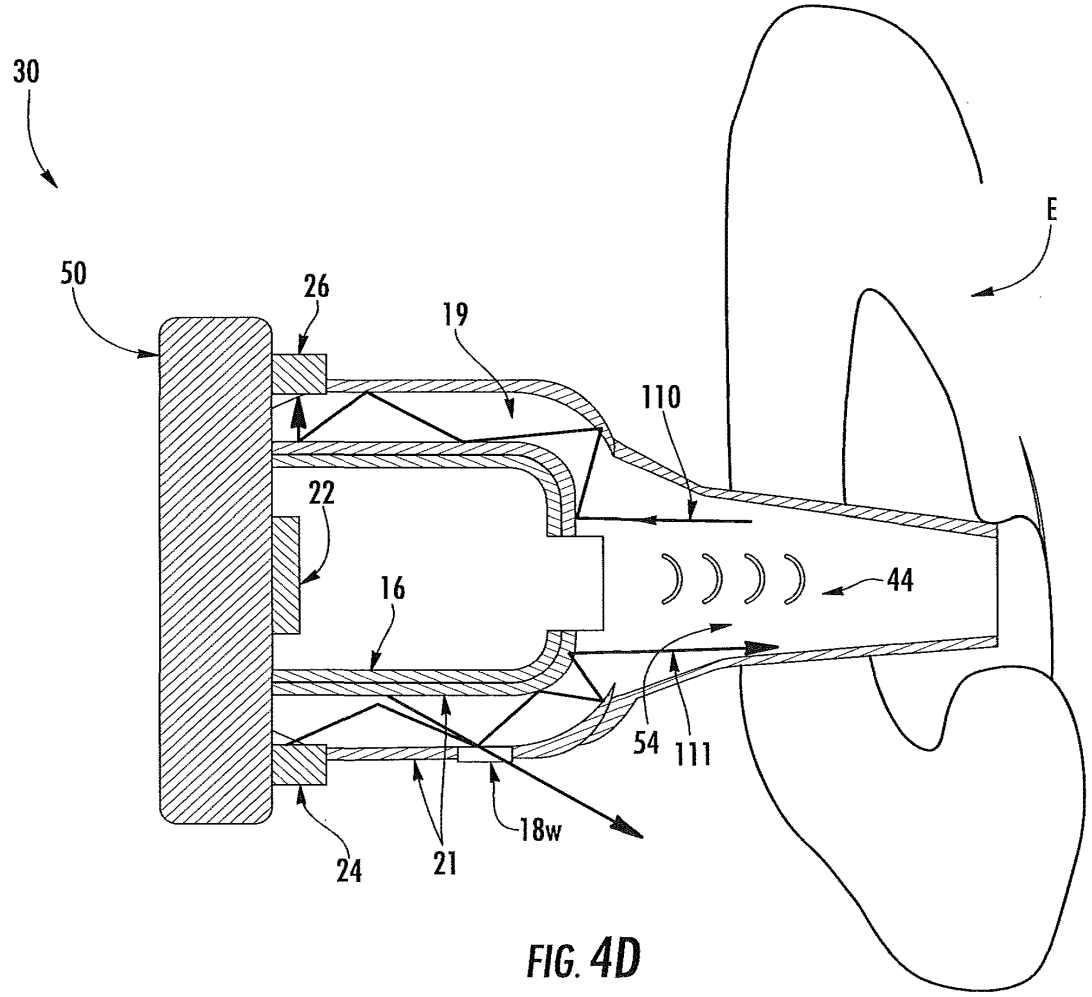


FIG. 4D

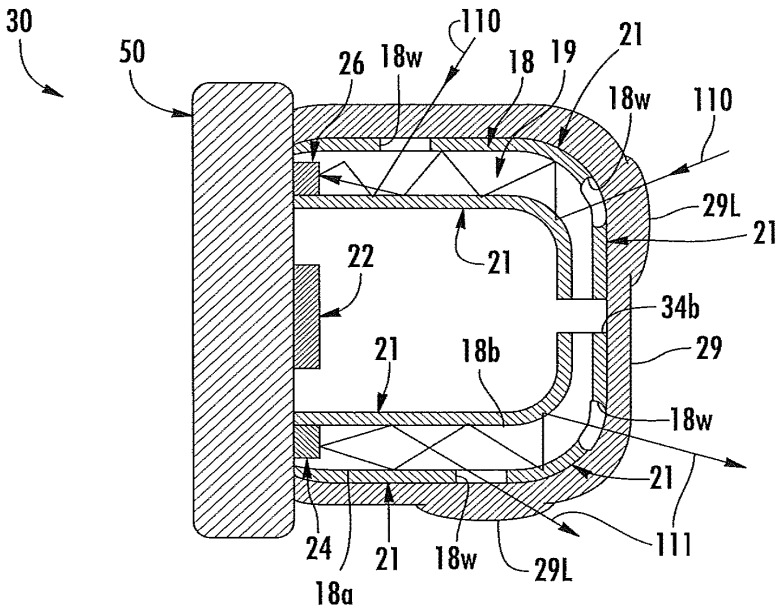


FIG. 5

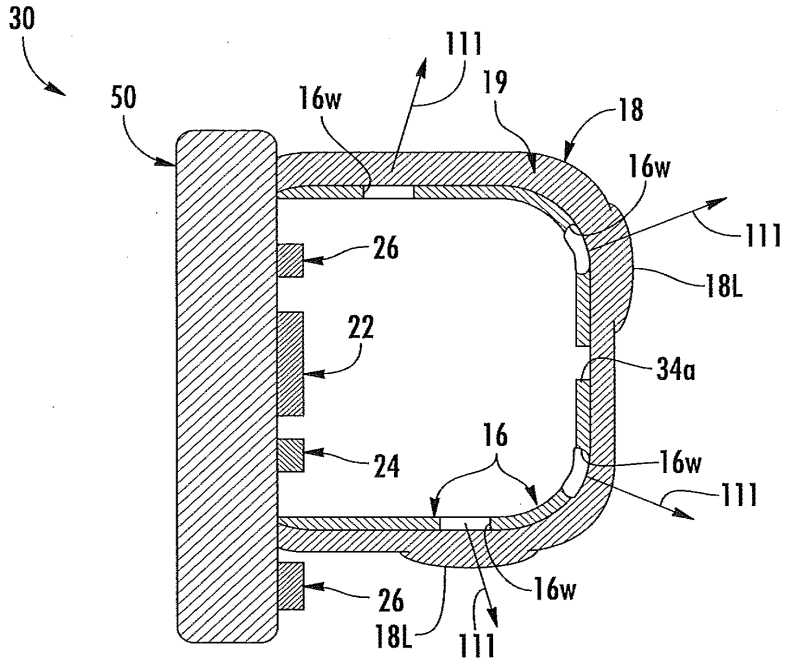


FIG. 6

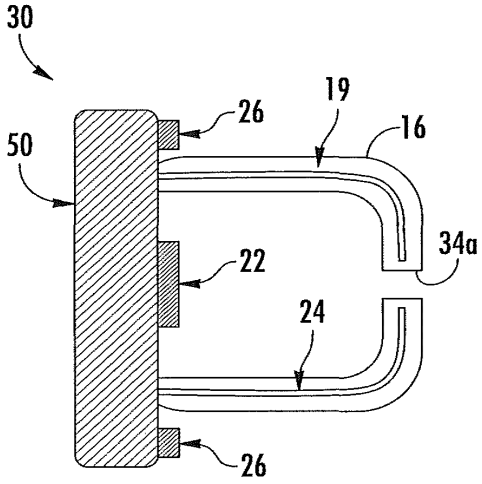


FIG. 7A

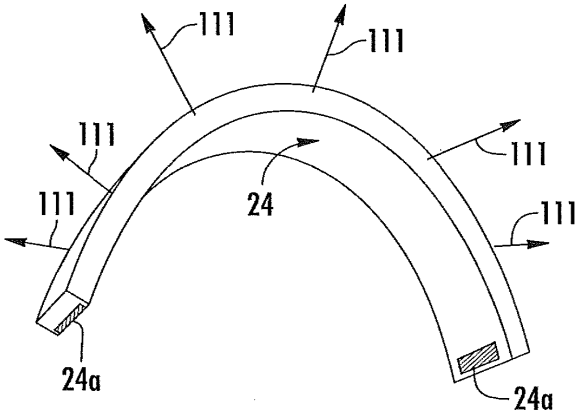


FIG. 7B

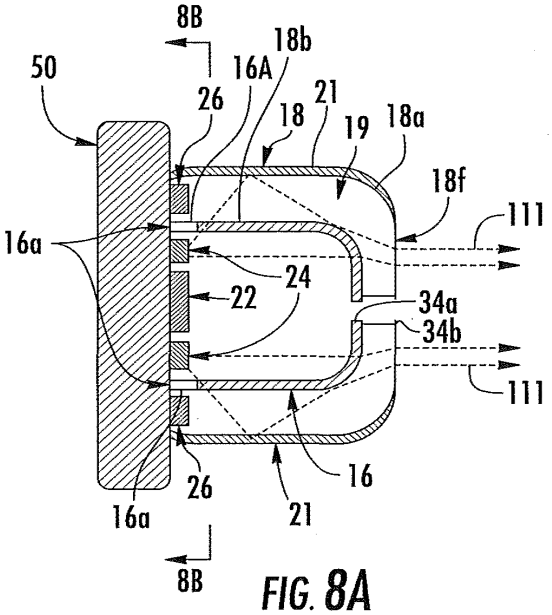


FIG. 8A

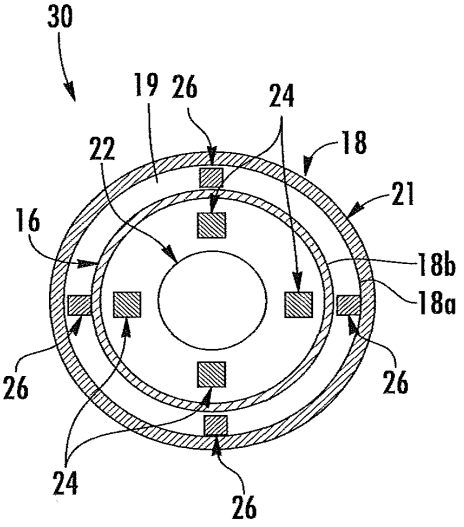


FIG. 8B

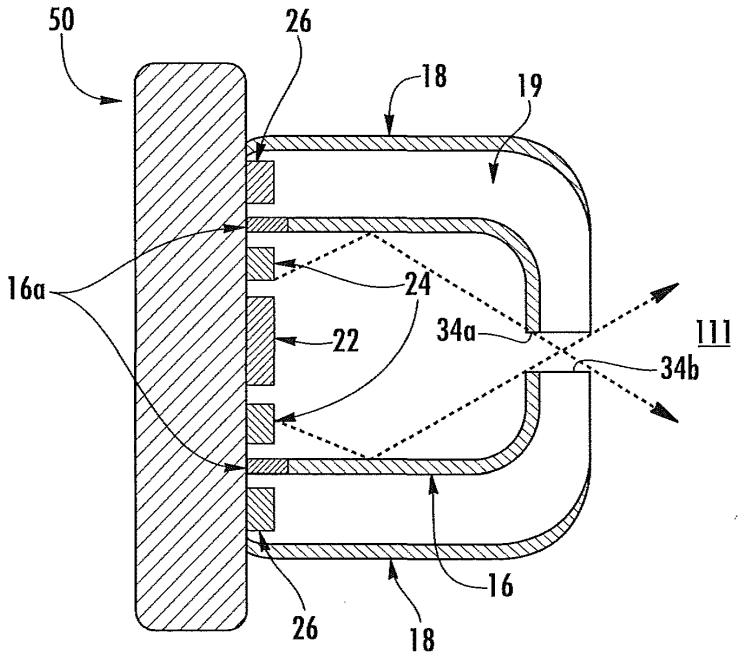


FIG. 8C

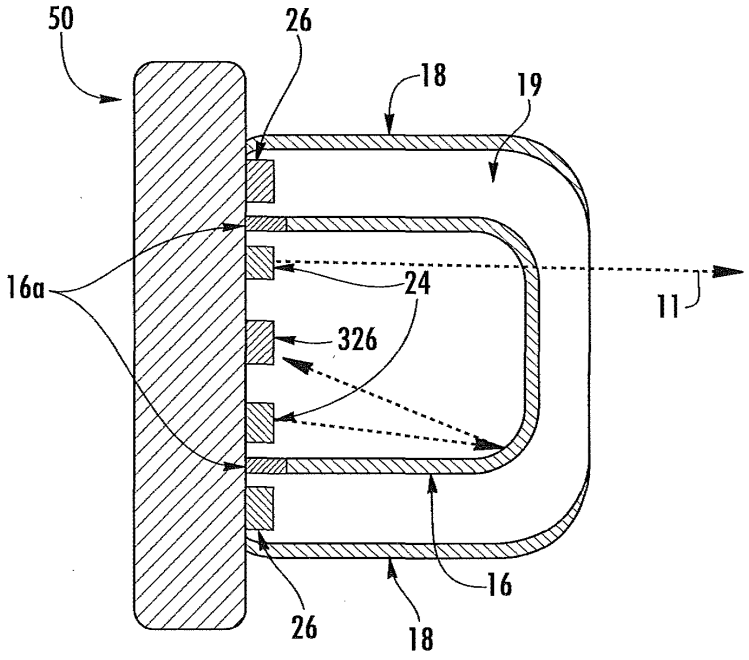


FIG. 8D

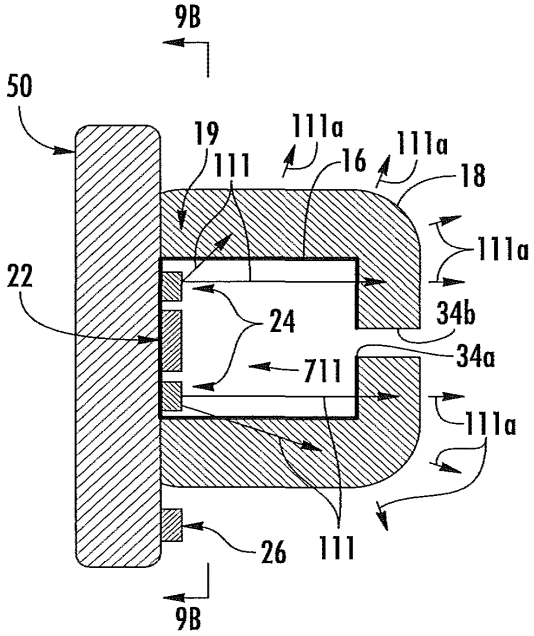


FIG. 9A

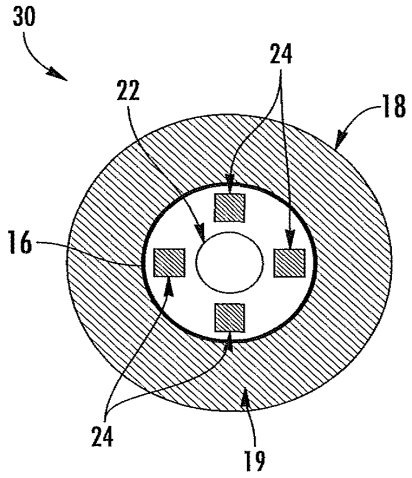


FIG. 9B

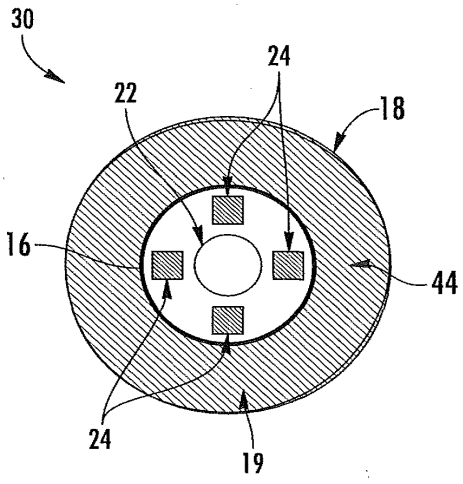


FIG. 9C

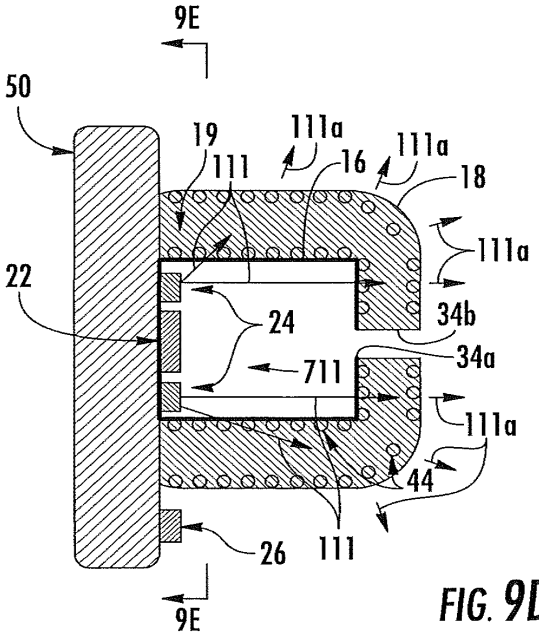


FIG. 9D

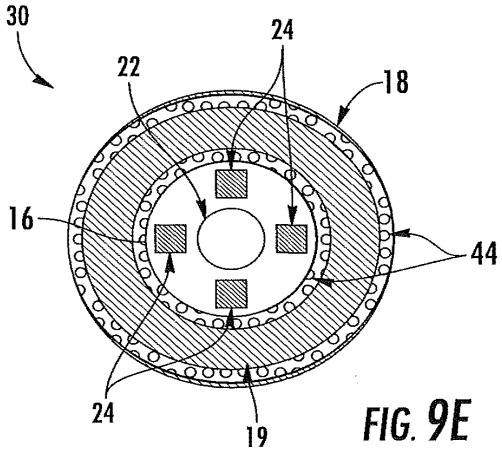


FIG. 9E

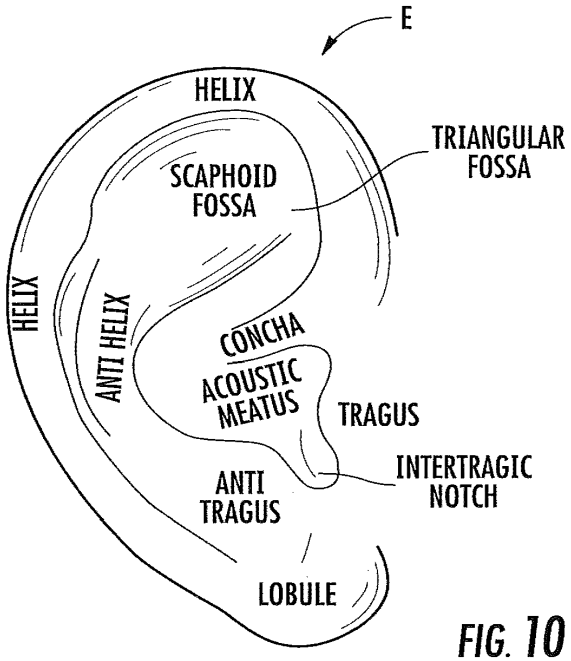


FIG. 10

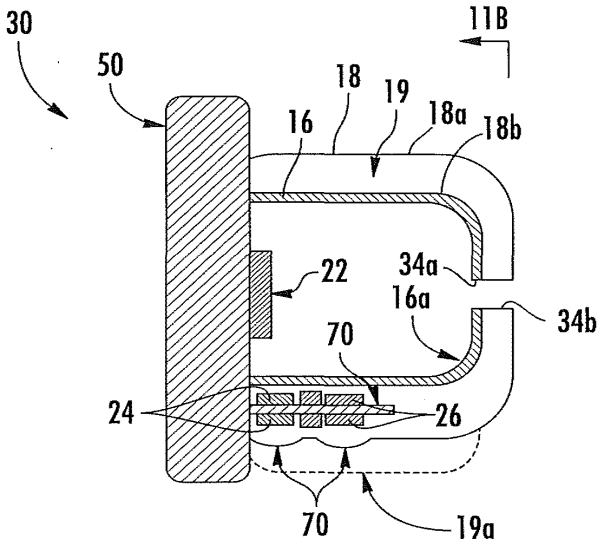


FIG. 11A

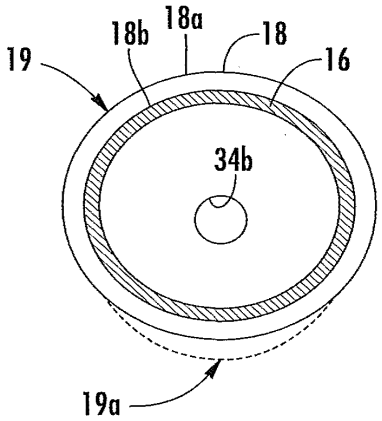
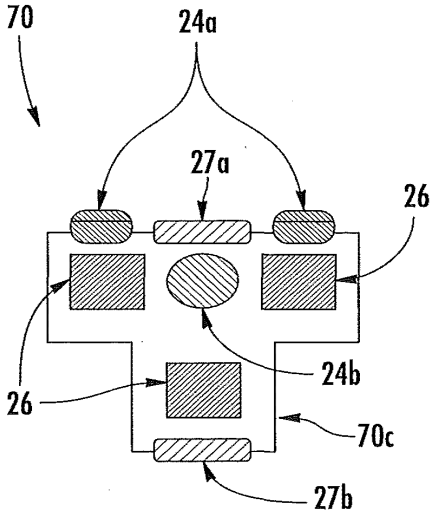
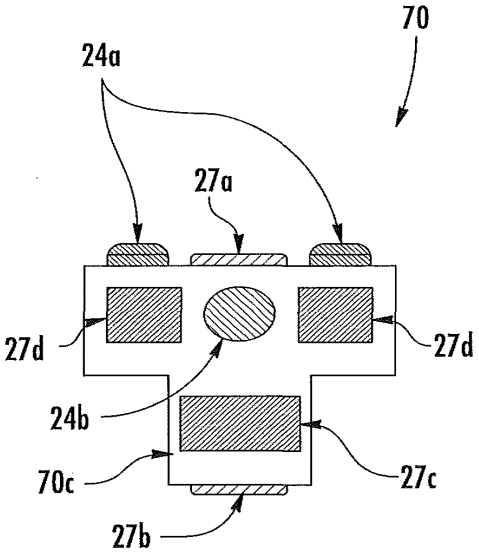


FIG. 11B



FACING ANTITRAGUS

FIG. 12A



FACING EARBUD

FIG. 12B

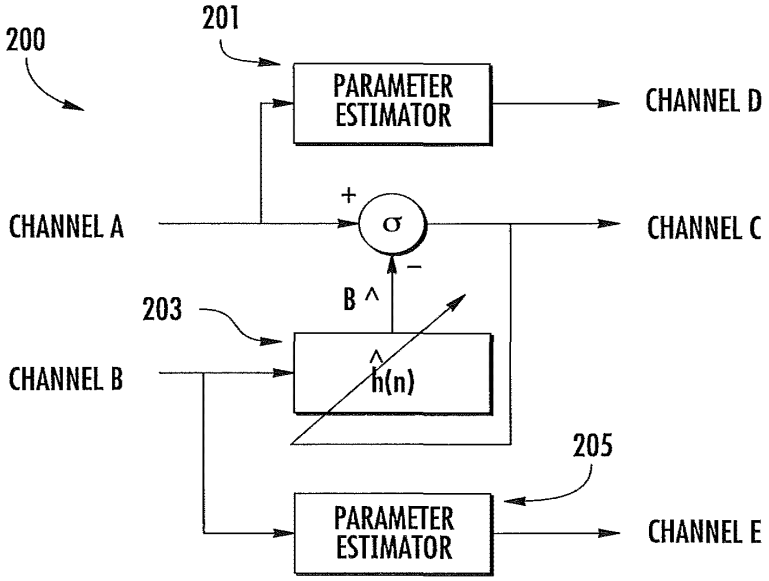


FIG. 13

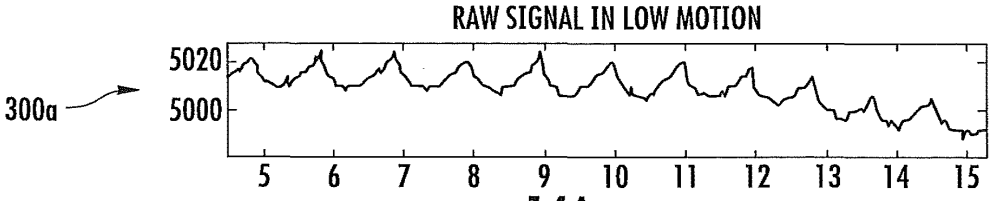


FIG. 14A

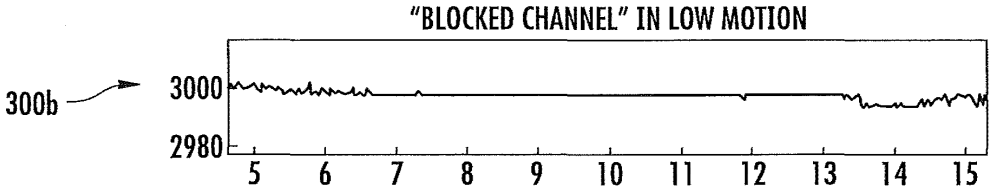


FIG. 14B

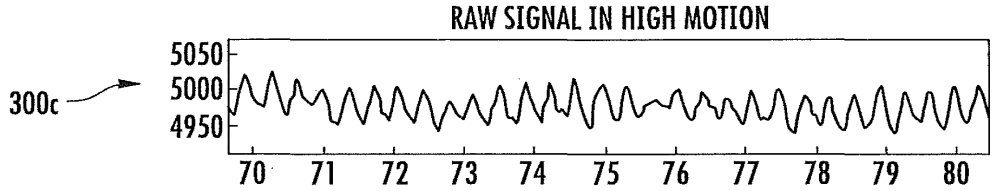


FIG. 14C

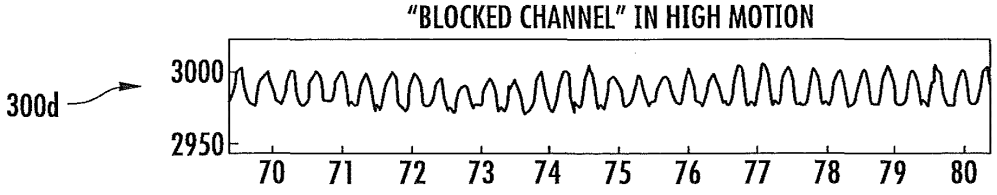


FIG. 14D

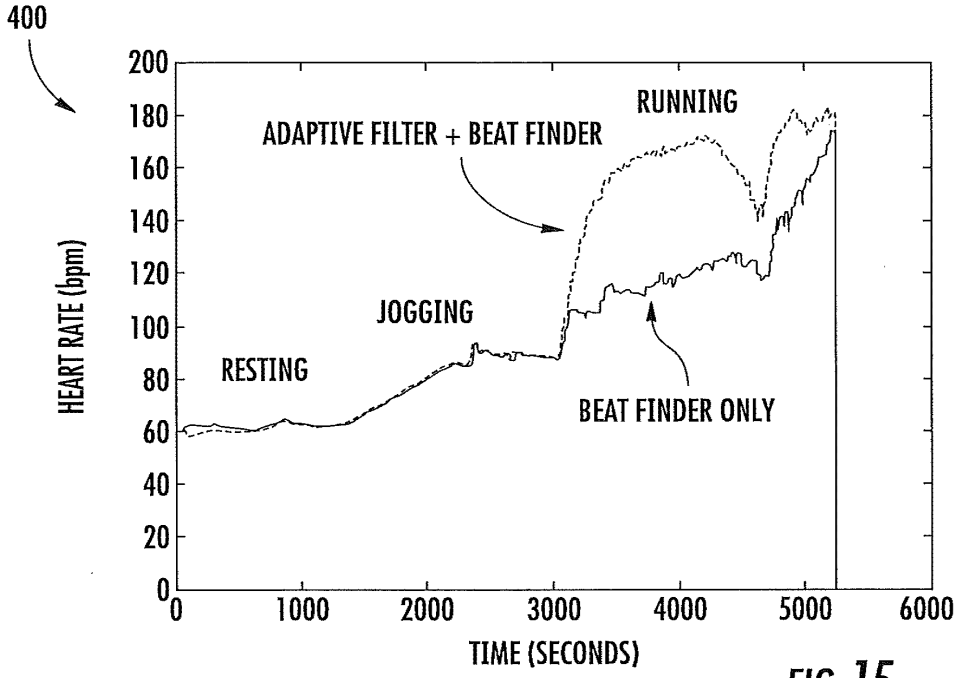


FIG. 15

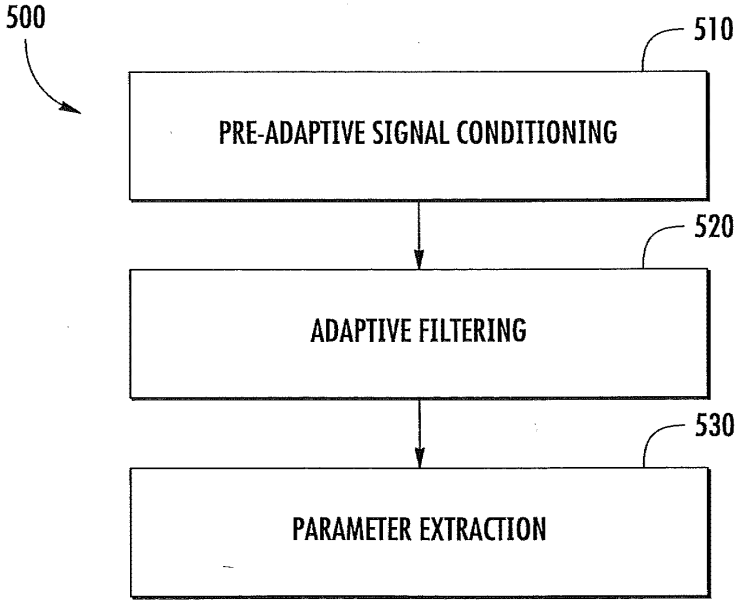


FIG. 16

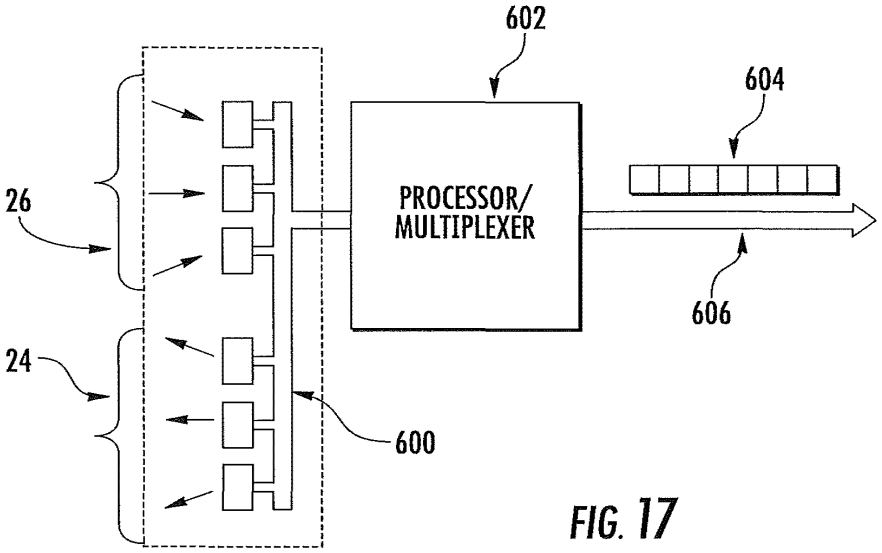


FIG. 17

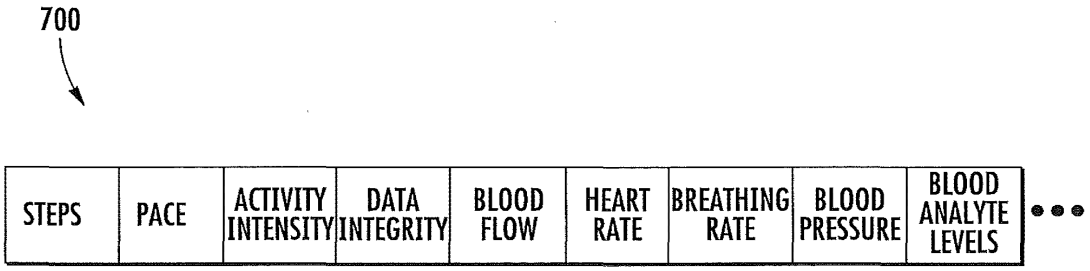


FIG. 18

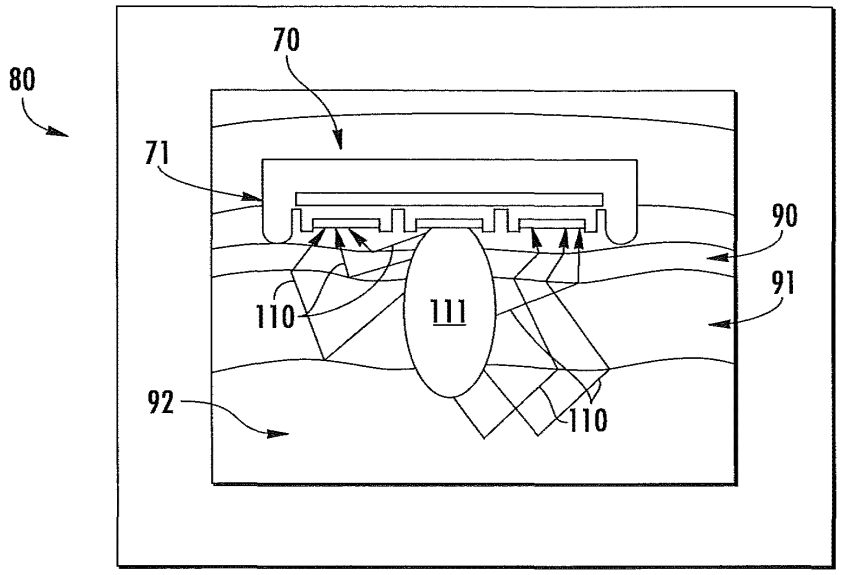


FIG. 19

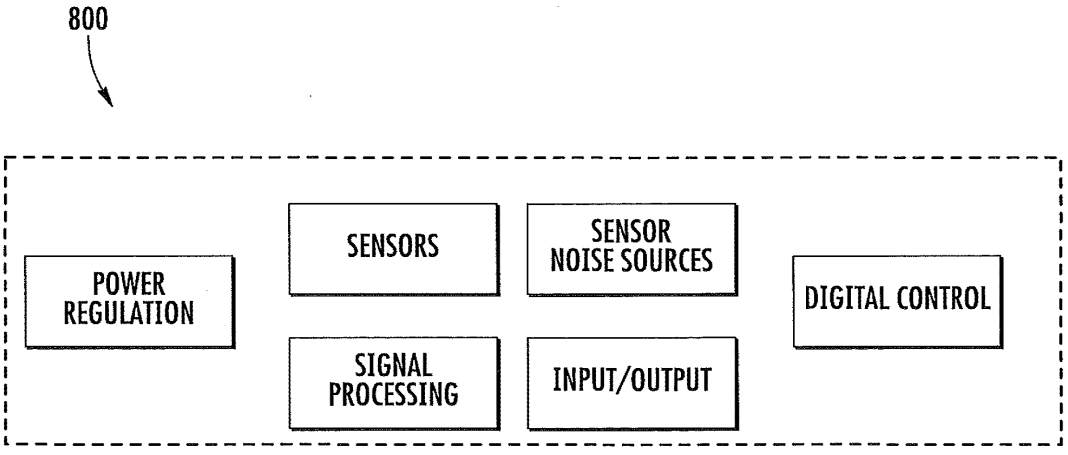


FIG. 20

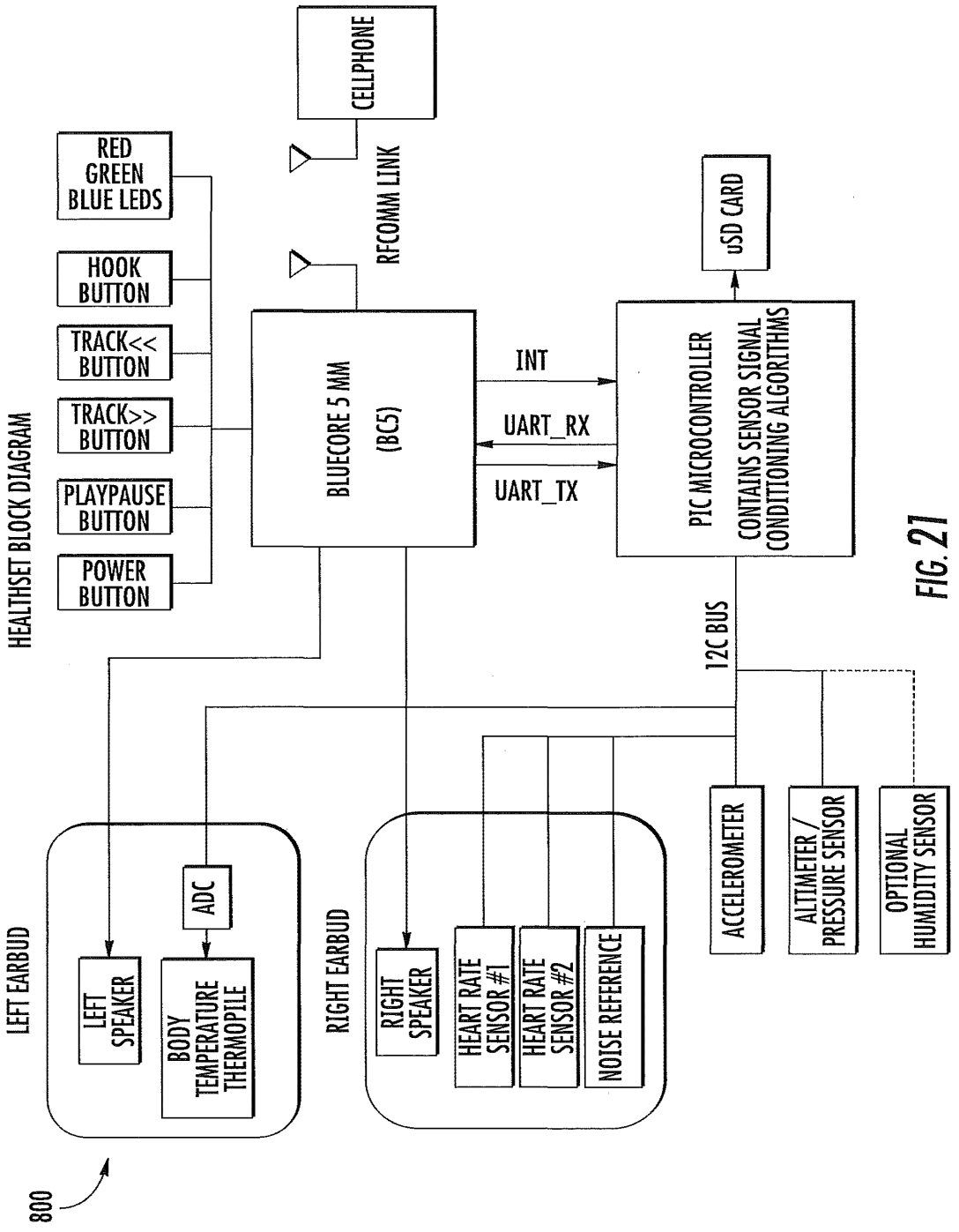


FIG. 21

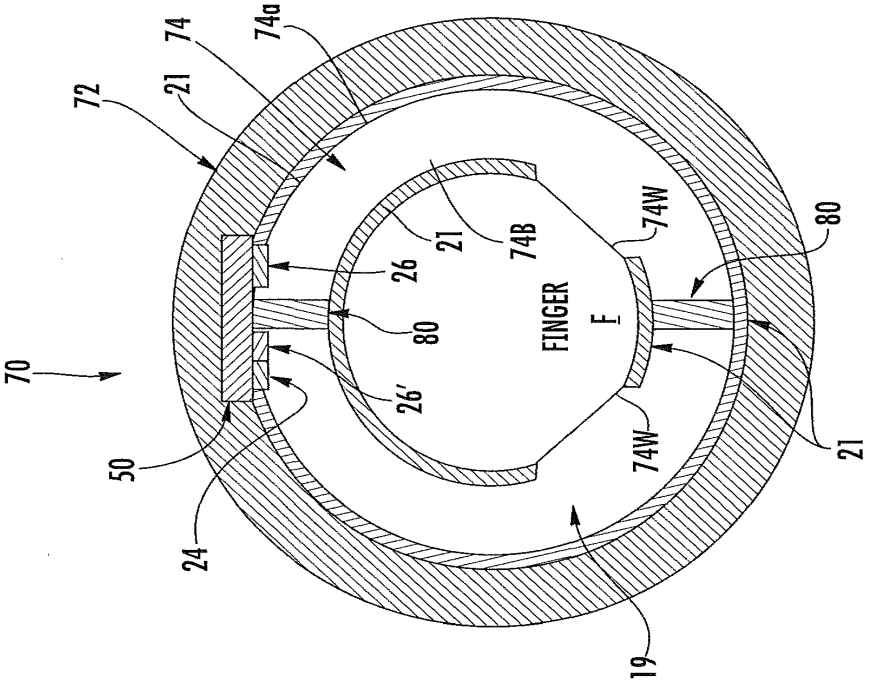


FIG. 22B

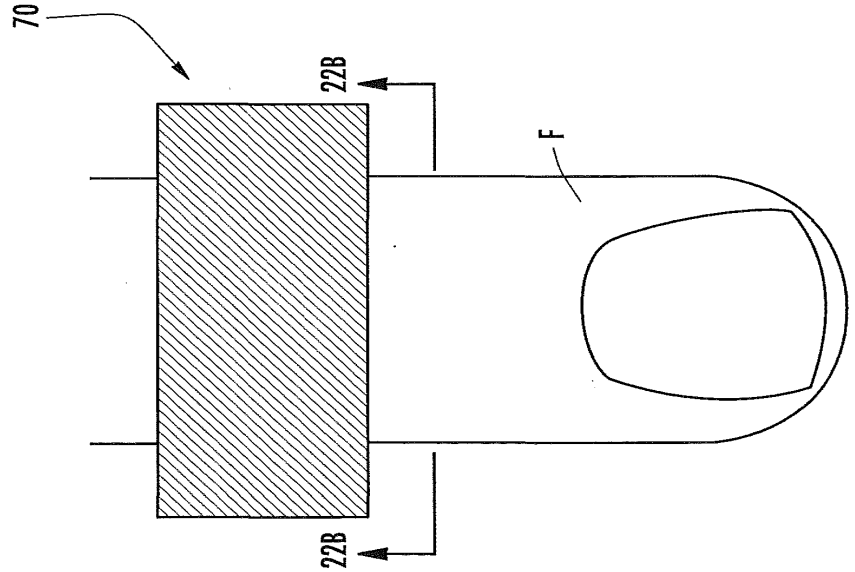


FIG. 22A

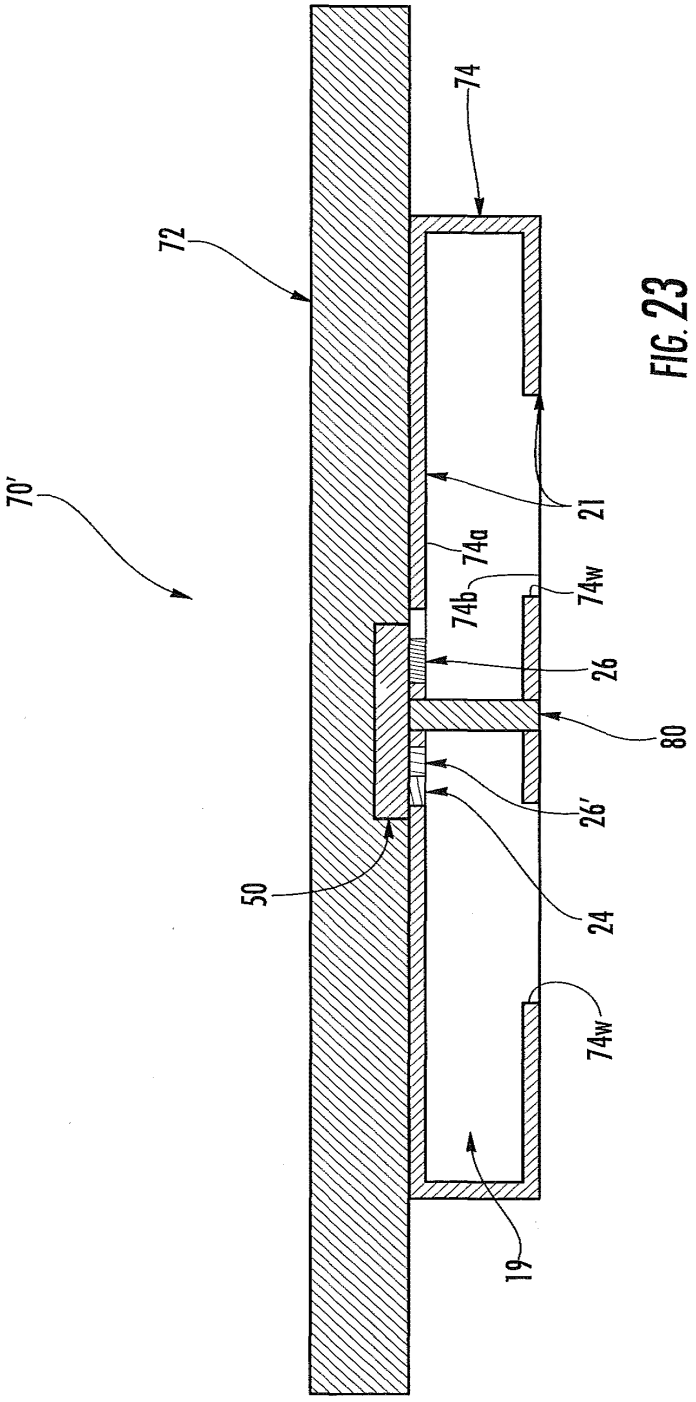


FIG. 23

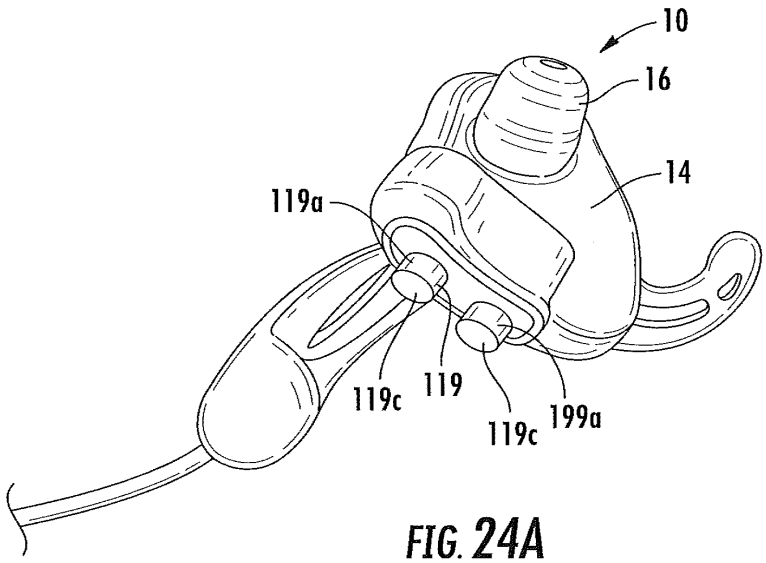


FIG. 24A

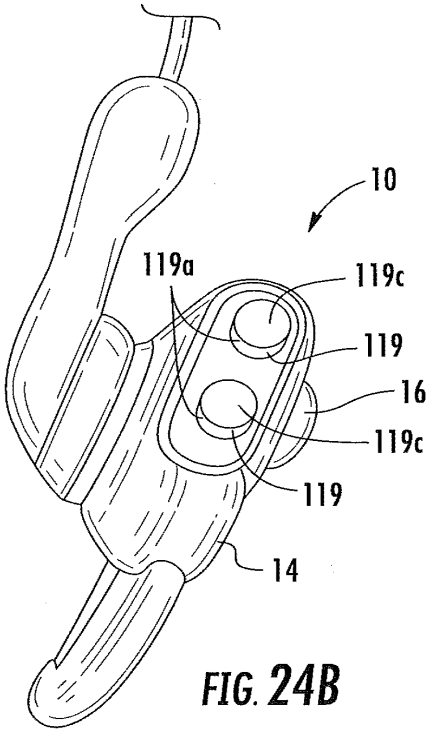


FIG. 24B

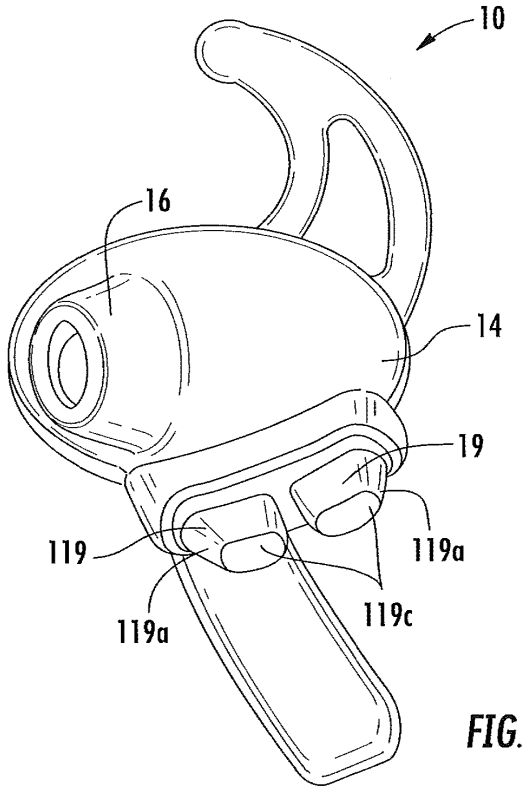


FIG. 25A

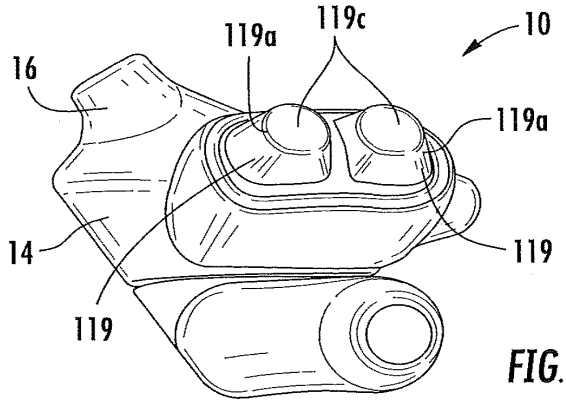


FIG. 25B

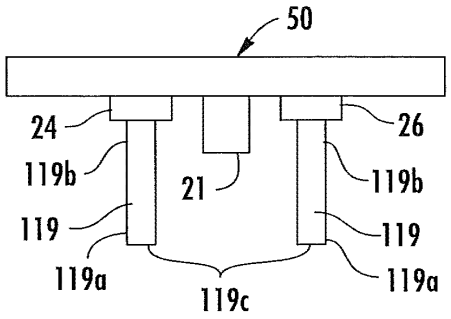


FIG. 26

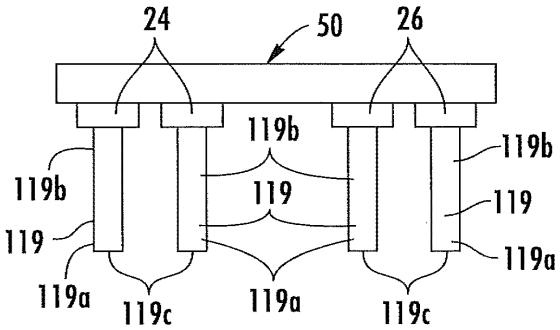


FIG. 27

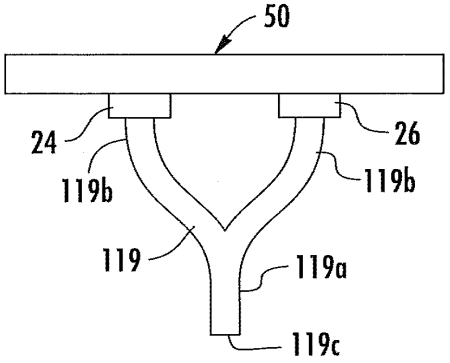


FIG. 28

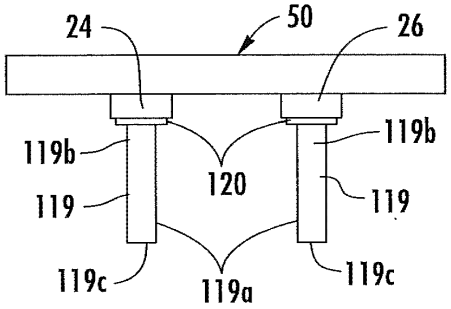


FIG. 29

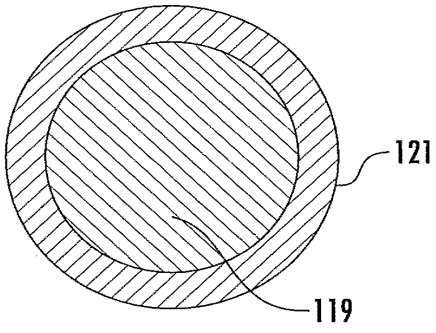


FIG. 30

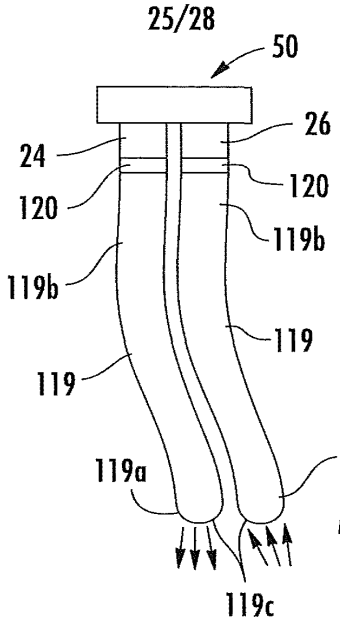


FIG. 31

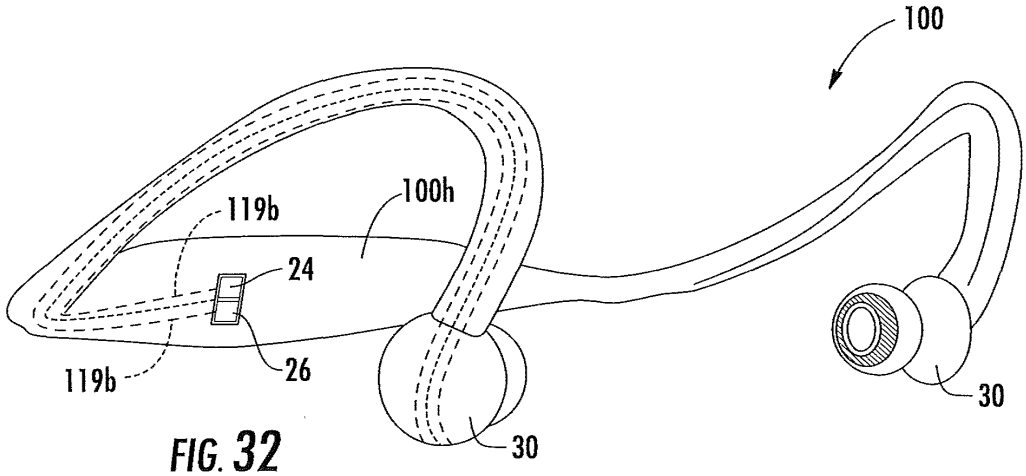


FIG. 32

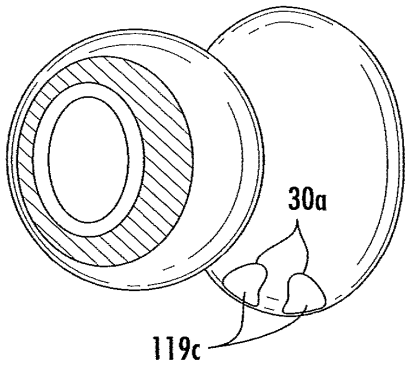


FIG. 33

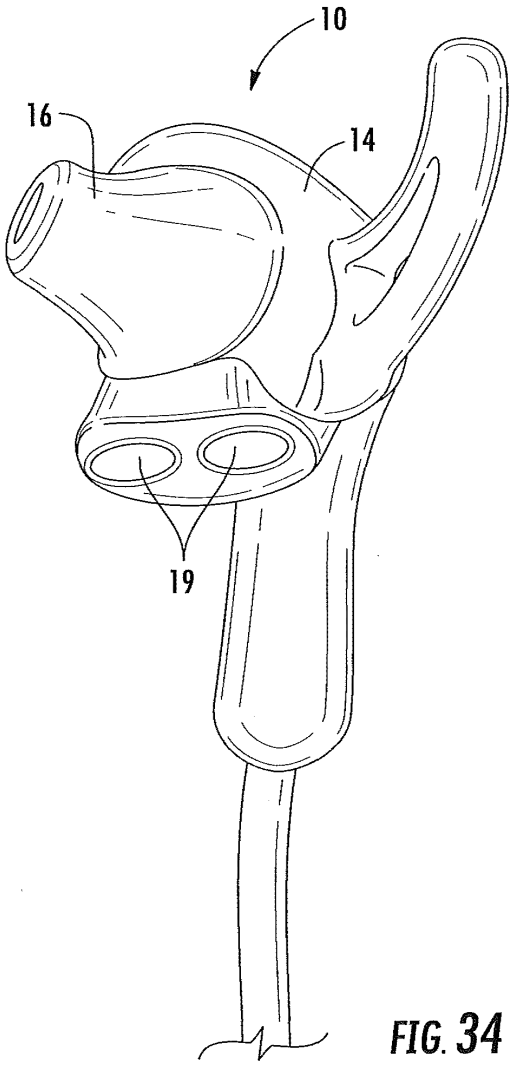


FIG. 34

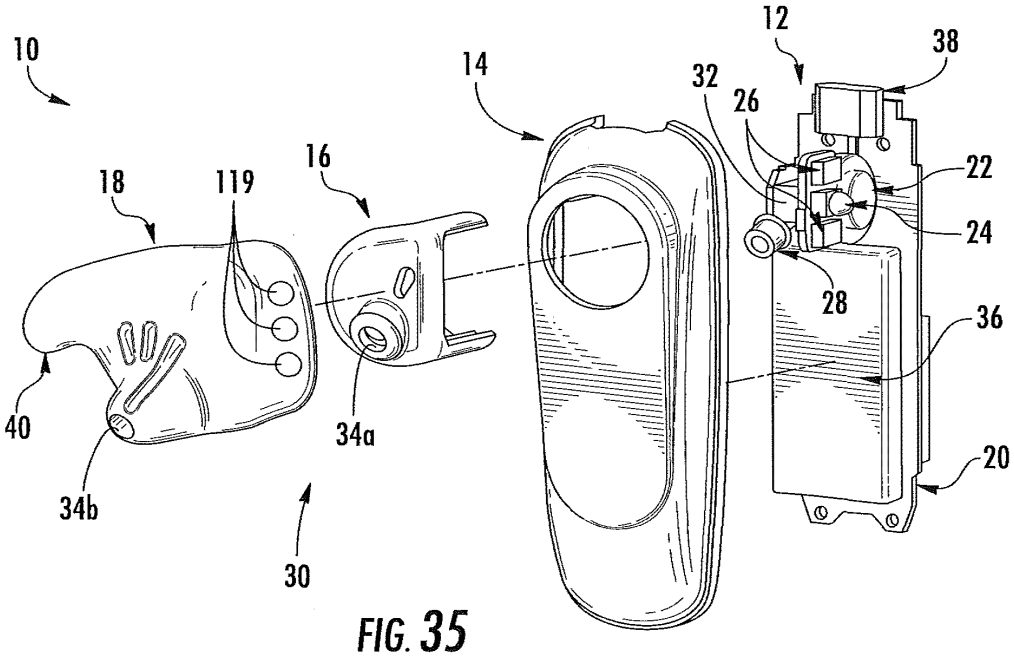


FIG. 35

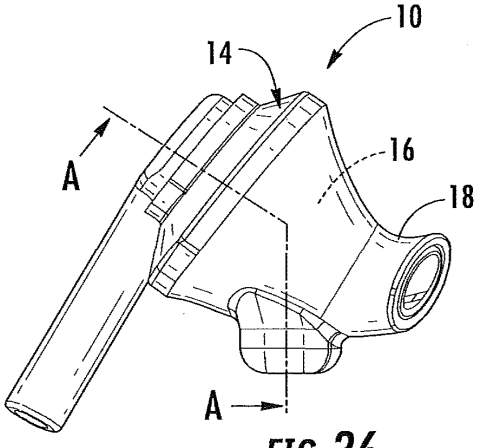


FIG. 36

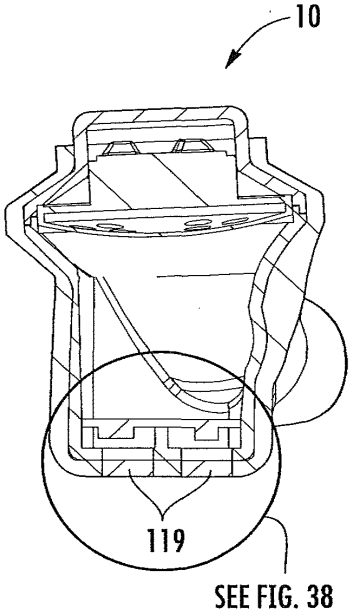


FIG. 37

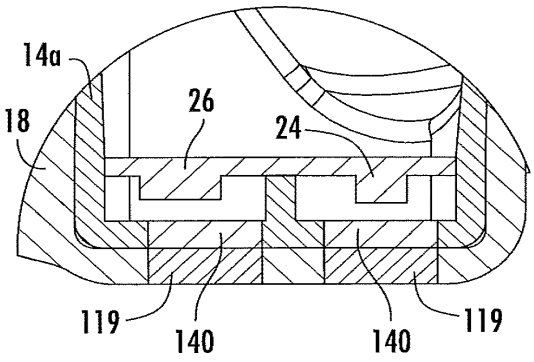


FIG. 38

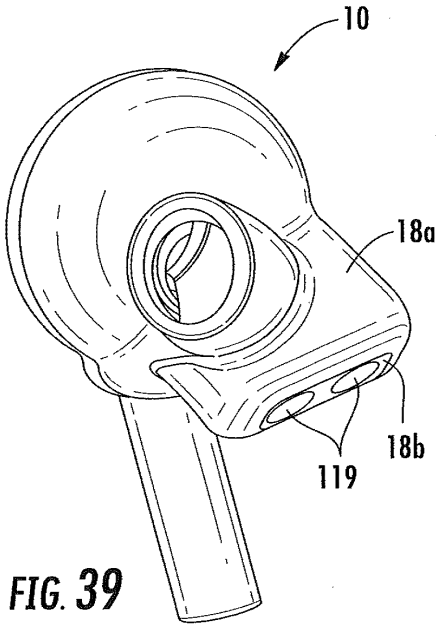


FIG. 39

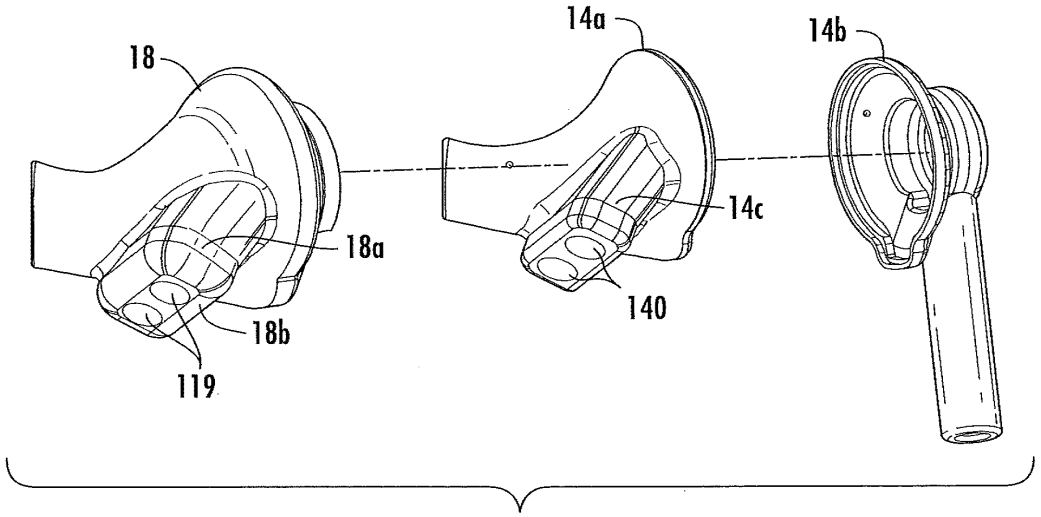


FIG. 40

DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN APPLICATION DATA SHEET (37 CFR 1.76)

Title of Invention	**LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME**

As a below named inventor, I hereby declare that:

This declaration is directed to:
- ☒ The attached application, or
- ☐ United States application or PCT international application number _____ filed on _____,
  - ☐ As amended on _____ (if applicable).

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment specifically referred to above.

I am aware of the duty to disclose information which is material to patentability as defined in 37 C.F.R. § 1.56, including for continuation-in-part applications, material information that became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

LEGAL NAME OF INVENTOR 1

Signature: _____ Date: 5/8/2014

Legal Name: **Steven Francis LeBoeuf**

LEGAL NAME OF INVENTOR 2 Signature: _____ Date: 5/8/2014 Legal Name: **Jesse Berkley Tucker**
LEGAL NAME OF INVENTOR 3 Signature: _____ Date: 5/8/14 Legal Name: **Michael Edward Aumer**
LEGAL NAME OF INVENTOR 4 Signature: _____ Date: 5/8/14 Legal Name: **Steven Matthew Just**

Attorney Docket No. 9653-7IPCT PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re: LeBoeuf et al.
Application No.: To Be Assigned
Filing Date: Concurrently Herewith
For: **LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME**

Date: May 9, 2014

Commissioner for Patents
Box 1450
Alexandria, VA 22313-1450

INFORMATION DISCLOSURE STATEMENT TRANSMITTAL

Sir:

Attached is an Information Disclosure Statement listing of documents previously of record in parent Application No. 12/691,388, filed January 21, 2010. As the benefit of this application is claimed under 35 U.S.C. § 120, no copies need to be furnished in accordance with 37 C.F.R. § 1.98(d); however, copies will be furnished on request.

☒ In accordance with **37 CFR 1.97(b)**, the information disclosure statement is being filed:

- ☒ (1) within three months of the filing date of a national application other than a continued prosecution application under §1.53(d);
- ☐ (2) within three months of the date of entry of the national stage as set forth in §1.491 in an international application;
- ☐ (3) before the mailing of a first Office Action on the merits; or
- ☐ (4) before the mailing of a first Office Action after the filing of a request for continued examination under §1.114.

☐ In accordance with **37 CFR 1.97(c)**, the information disclosure statement is being filed after the period specified in 37 CFR 1.97(b) above, but before the mailing date of any of a final action under §1.113, a notice of allowance under §1.311, or an action that otherwise closes prosecution in the application, and is accompanied by **one** of the following:

☐ (1) The statement specified under **37 CFR 1.97(e)**, as follows:

☐ Each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement; **or**

☐ No item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement; **or**

☐ (2) The fee set forth in §1.17(p);

☐ In accordance with **37 CFR 1.97(d)**, the information disclosure statement is being filed after the period specified in 37 CFR 1.97(c) above, but on or before payment of the issue fee, and is accompanied by **both** of the following:

☐ (1) The statement specified under **37 CFR 1.97(e)**, as follows:

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement; **or**

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement; **and**

☐ (2) The fee set forth in §1.17(p);

In accordance with **37 CFR 1.97(g)**, the information disclosure statement shall not be construed as a representation that a search has been made.

In accordance with **37 CFR 1.97(h)**, the information disclosure statement shall not be construed to be an admission that the information cited in the statement is, or is considered to be, material to patentability as defined in §1.56(b).

☐ The Director is hereby authorized to charge the fee specified in 37 C.F.R. § 1.17(p), and any fee deficiency or credit any overpayment, to Deposit Account No. 50-0220; or

☒ No fee is believed due. However, the Director is hereby authorized to charge any deficiency or credit any overpayment to Deposit Account No. 50-0220.

Respectfully submitted,

N J Boddie II

Needham J. Boddie, II
Registration No. 40,519
Attorney for Applicant(s)

Customer Number 20792
Myers Bigel Sibley & Sajovec, P.A.
P.O. Box 37428, Raleigh, NC 27627
919-854-1400
919-854-1401 (Fax)

CERTIFICATION OF TRANSMISSION

I hereby certify that this correspondence is being transmitted via the Office electronic filing system in accordance with 37 CFR § 1.6(a)(4) to the U.S. Patent and Trademark Office on May 9, 2014.

Gwen R. Bailey

Gwen R. Bailey

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (use as many sheets as necessary)				Complete if Known	
				Application Number	To Be Assigned
				Filing Date	Concurrently Herewith
				First Named Inventor	Steven Francis LeBoeuf
				Art Unit	
				Examiner Name	
Sheet	A1	of	A2	Attorney Docket Number	9653-7IPCT

U.S. PATENT DOCUMENTS					
Examiner Initials*	Cite No.	Document Number Number-Kind Code (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	1.	US- 2013/0131519	05-2013	LeBoeuf et al.	
	2.	US- 2012/0197093	08-2012	LeBoeuf et al.	
	3.	US- 2011/0105869 A1	05-2011	Wilson et al.	
	4.	US- 2010/0298653	11-2010	McCombie et al.	
	5.	US- 2010/0217103 A1	08-26-2010	Abdul-Hafiz; Yassir et al.	
	6.	US- 2010/0168531	07-2010	Shaltis et al.	
	7.	US- 2009/0287067 A1	11-2009	Dorogusker et al.	
	8.	US- 2009/0270698 A1	10-2009	Shioi et al.	
	9.	US- 2009/0105556 A1	04-2009	Fricke et al.	
	10	US- 2009/0054752 A1	02-2009	Jonnalagadda et al.	
	11	US- 2009/0030350 A1	01-29-2009	Yang et al.	
	12	US- 2008/0177162 A1	07-2008	Bae et al.	
	13	US- 2008/0165017 A1	07-2008	Schwartz	
	14	US- 2008/0096726 A1	04-2008	Riley et al.	
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FOREIGN PATENT DOCUMENTS					
Examiner	Cite	Foreign Patent Document	Publication Date	Name of Patentee or	Pages, Columns, Lines,

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (use as many sheets as necessary)				Complete if Known	
				Application Number	To Be Assigned
				Filing Date	Concurrently Herewith
				First Named Inventor	Steven Francis LeBoeuf
				Art Unit	
				Examiner Name	
Sheet	A2	of	A2	Attorney Docket Number	9653-7IPCT

Initials*	No.	Country Code, Number, Kind Code (if known)	MM-DD-YYYY	Applicant of Cited Document	Where Relevant Passages or Relevant Figures Appear	T
	34	JP 2007-185348	07-26-2007	OLYMPUS CORP		A
	35	JP 2001-25462	01-30-2001	DENSO CORP		A
	36	JP 2000-116611	04-25-2000	KOWA SPINNING CO LTD		A
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	39	JP 7-241279	09-19-1995	NIPPON KODEN CORP		A

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published	T
	40	FITRAINER "The Only Trainer You Need"; http://itami.com; Downloaded 2/26/2010; ©2008 FiTriainer™; 2 pages	

Examiner Signature		Date Considered	

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Doc Code: PA..
Document Description: Power of Attorney

PTO/AIA/82A (07-13)
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Application Number	To Be Assigned
Filing Date	Concurrently Herewith
First Named Inventor	Steven Francis LeBoeuf
Title	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME
Art Unit	
Examiner Name	
Attorney Docket Number	9653-7IPCT

SIGNATURE of Applicant or Patent Practitioner

Signature	NJ Boddie II	Date (Optional)	May 9, 2014
Name	Needham J. Boddie, II	Registration Number	40,519
Title (if Applicant is a juristic entity)	Attorney		
Applicant Name (if Applicant is a juristic entity)			

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.

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Application Number	Filing Date

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OR

Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the Applicant (if the Applicant is a juristic entity, list the Applicant name in the box):

Valencell, Inc.

☐ Inventor or Joint Inventor (title not required below)

☐ Legal Representative of a Deceased or Legally Incapacitated Inventor (title not required below)

☑ Assignee or Person to Whom the Inventor is Under an Obligation to Assign (provide signer's title if applicant is a juristic entity)

☐ Person Who Otherwise Shows Sufficient Proprietary Interest (e.g., a petition under 37 CFR 1.46(b)(2) was granted in the application or is concurrently being filed with this document) (provide signer's title if applicant is a juristic entity)

SIGNATURE of Applicant for Patent

The undersigned (whose title is supplied below) is authorized to act on behalf of the applicant (e.g., where the applicant is a juristic entity).

Signature	[signature]	Date (Optional)	January 24, 2014
Name	Todd Ackman		
Title	Vice President of Finance, Valencell, Inc.		

NOTE: Signature - This form must be signed by the applicant in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. If more than one applicant, use multiple forms.

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Electronic Patent Application Fee Transmittal

Application Number:	
Filing Date:	
Title of Invention:	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME
First Named Inventor/Applicant Name:	Steven Francis LeBoeuf
Filer:	Needham J. Boddie/Gwen Bailey
Attorney Docket Number:	9653-7IPCT

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility application filing	1011	1	280	280
Utility Search Fee	1111	1	600	600
Utility Examination Fee	1311	1	720	720
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1600**

Electronic Acknowledgement Receipt	
EFS ID:	18993554
Application Number:	14274288
International Application Number:	
Confirmation Number:	9722
Title of Invention:	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME
First Named Inventor/Applicant Name:	Steven Francis LeBoeuf
Customer Number:	20792
Filer:	Needham J. Boddie/Gwen Bailey
Filer Authorized By:	Needham J. Boddie
Attorney Docket Number:	9653-7IPCT
Receipt Date:	09-MAY-2014
Filing Date:	
Time Stamp:	16:59:27
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$1600
RAM confirmation Number	3336
Deposit Account	500220
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal of New Application	9653-7IPCT_ApplicationTransmittal.pdf	149170 9a91ca497a23d4b73ed6448a3f83811426b05b05	no	1
Warnings:					
Information:					
2	Application Data Sheet	9653-7IPCT_ApplicationDataSheet.pdf	850345 1d6aab930e513964449a092222969ae7ac395280	no	7
Warnings:					
Information:					
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3		9653-7IPCT_Application.pdf	8528716 1ca79fffd8e218a30f5ed0df6f31195b963798a1	yes	66

Multipart Description/PDF files in .zip description

Document Description	Start	End
Specification	1	61
Claims	62	65
Abstract	66	66

Warnings:					
Information:					
4	Drawings-only black and white line drawings	9653-7IPCT_Drawings.pdf	1715448 39e9f3cea026876420262d307c00a26cdff77050	no	28
Warnings:					
Information:					
5	Oath or Declaration filed	9653-7IPCT_Declaration.pdf	161161 01f3a44bfa2ae4f4c63a419002c2dfaa3b4d6799	no	2
Warnings:					
Information:					
6		9653-7IPCT_IDS.pdf	459486 a963e591fabc219bcca44c65c12a430d8efa4f32	yes	4

Multipart Description/PDF files in .zip description

Document Description	Start	End

	Transmittal Letter		1		2
	Information Disclosure Statement (IDS) Form (SB08)		3		4
Warnings:					
Information:					
7	Power of Attorney	9653-7IPCT_POA.pdf	321743 66c3299408a24133e38abf5ad1782ab33ab34018	no	2
Warnings:					
Information:					
8	Fee Worksheet (SB06)	fee-info.pdf	33344 27e9eabfcbad0018bb087b6346c57aa44036a0e4	no	2
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Attorney Docket No.: 9653-7IPCT **PATENT**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re: LeBoeuf et al. Confirmation No. 9722
Serial No.: 14/274,288
Filed: May 9, 2014

For: LIGHT GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME

Date: May 12, 2014

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

PRELIMINARY AMENDMENT

Prior to the examination of the above-referenced application, please enter the following amendments and consider the remarks below. Applicants provide the present Amendment pursuant to the rules stated in revised 37 C.F.R. 1.121 that became effective on July 30, 2003.

Amendments to the Abstract begin on page 2 of this paper.

A Listing of the Claims begin on page 3 of this paper.

Remarks begin on page 7 of this paper.

In the Abstract:

On page 66, please replace the existing Abstract with the following:

-- A sensor module for detecting and/or measuring physiological information from a subject includes a housing with at least one optical emitter and at least one optical detector supported by the housing. A first light guide is in optical communication with the at least one optical emitter and is configured to deliver light from the at least one optical emitter into a body of a subject. A second light guide is in optical communication with the at least one optical detector and is configured to collect light from the body of the subject. The sensor module includes a motion sensor and a processor. The motion sensor is configured to sense motion information from the subject and the processor is configured to remove motion artifacts from signals produced by the at least one optical detector in response to signals produced by the motion sensor. --

Listing of Claims:

1. (Original) A sensor module for detecting and/or measuring physiological information from a subject, the sensor module comprising:

a housing;

at least one optical emitter supported by the housing;

at least one optical detector supported by the housing;

a first light guide supported by the housing, wherein the first light guide is in optical communication with the at least one optical emitter, wherein the first light guide comprises a distal end, and wherein the first light guide is configured to deliver light from the at least one optical emitter into a body of the subject via the distal end thereof; and

a second light guide supported by the housing, wherein the second light guide is in optical communication with the at least one optical detector, wherein the second light guide comprises a distal end, and wherein the second light guide is configured to collect light from the body of the subject via the distal end thereof and deliver collected light to the at least one optical detector.

2. (Original) The sensor module of Claim 1, wherein the housing is configured to be integrated within an audio headset, a wrist strap, a wrist watch, an ankle bracelet, or an armband.

3. (Original) The sensor module of Claim 1, further comprising at least one motion sensor supported by the housing, wherein the at least one motion sensor is configured to sense motion information from the subject.

4. (Original) The sensor module of Claim 3, further comprising at least one processor supported by the housing, wherein the at least one processor is configured to remove motion artifacts from signals produced by the at least one optical detector in response to signals produced by the at least one motion sensor.

5. (Original) The sensor module of Claim 1, wherein the first light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by first light guide.

6. (Original) The sensor module of Claim 1, wherein the second light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by second light guide.

7. (Original) The sensor module of Claim 1, wherein at least one of the first and second light guides comprises elastomeric light transmissive material.

8. (Original) The sensor module of Claim 1, wherein at least one of the first and second light guides comprises substantially rigid light transmissive material.

9. (Original) The sensor module of Claim 1, wherein the at least one optical emitter comprises optical coupling material, and wherein the first light guide is in optical communication with the at least one optical emitter via the optical coupling material.

10. (Original) The sensor module of Claim 1, wherein the at least one optical detector comprises optical coupling material, and wherein the second light guide is in optical communication with the at least one optical detector via the optical coupling material.

11. (Original) The sensor module of Claim 3, further comprising at least one processor supported by the housing, wherein the at least one processor is configured to process signals produced by the at least one optical detector and signals produced by the at least one motion sensor to determine subject heart rate and respiration rate.

12. (Original) A sensor module for detecting and/or measuring physiological information from a subject, the sensor module, comprising:

a housing;

at least one optical emitter supported by the housing;

at least one optical detector supported by the housing;

a first light guide supported by the housing, wherein the first light guide is in optical communication with the at least one optical emitter, and wherein the first light guide is configured to deliver light from the at least one optical emitter into a body of the subject;

a second light guide supported by the housing, wherein the second light guide is in optical communication with the at least one optical detector, and wherein the second light guide is configured to collect light from the body of the subject;

a motion sensor supported by the housing, wherein the motion sensor is configured to sense motion information from the subject; and

a processor supported by the housing, wherein the processor is configured to remove motion artifacts from signals produced by the at least one optical detector in response to signals produced by the motion sensor, and wherein the processor is configured to process signals produced by the at least one optical detector to determine subject heart rate and respiration rate.

13. (Original) The sensor module of Claim 12, wherein the housing is configured to be integrated within an audio headset, a wrist strap, a wrist watch, an ankle bracelet, or an armband.

14. (Original) The sensor module of Claim 12, wherein the first light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by first light guide.

15. (Original) The sensor module of Claim 12, wherein the second light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by second light guide.

16. (Original) The sensor module of Claim 12, wherein at least one of the first and second light guides comprises elastomeric light transmissive material.

17. (Original) The sensor module of Claim 12, wherein at least one of the first and second light guides comprises substantially rigid light transmissive material.

18. (Original) The sensor module of Claim 12, wherein the at least one optical emitter comprises optical coupling material, and wherein the first light guide is in optical communication with the at least one optical emitter via the optical coupling material.

19. (Original) The sensor module of Claim 12, wherein the at least one optical detector comprises optical coupling material, and wherein the second light guide is in optical communication with the at least one optical detector via the optical coupling material.

20. (Original) A sensor module for detecting and/or measuring physiological information from a subject, the sensor module, comprising:

a housing;

an optical emitter supported by the housing;

an optical detector supported by the housing;

a first light guide supported by the housing, wherein the first light guide is in optical communication with the optical emitter, wherein the first light guide comprises a distal free end, and wherein the first light guide is configured to deliver light from the optical emitter into a body of the subject via the distal end thereof; and

a second light guide supported by the housing, wherein the second light guide is in optical communication with the optical detector, wherein the second light guide comprises a distal free end, and wherein the second light guide is configured to collect light from the body of the subject via the distal end thereof and deliver collected light to the optical detector,

wherein the distal free ends of the first and second light guides are in adjacent, spaced-apart relationship.

REMARKS

Applicants have amended the Abstract, as indicated above.

Claims 1-20 are to be examined in the present continuation application. Entry of this Preliminary Amendment, examination of the application, and allowance of the application, including Claims 1-20 are respectfully requested.

Respectfully submitted,

Needham J. Boddie, II
Attorney for Applicants
Registration No. 40,519

USPTO Customer No. 20792
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Telephone: (919) 854-1400
Facsimile: (919) 854-1401
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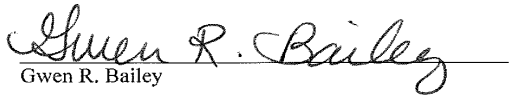

Gwen R. Bailey

Electronic Acknowledgement Receipt

EFS ID:	19006502
Application Number:	14274288
International Application Number:	
Confirmation Number:	9722
Title of Invention:	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME
First Named Inventor/Applicant Name:	Steven Francis LeBoeuf
Customer Number:	20792
Filer:	Needham J. Boddie/Gwen Bailey
Filer Authorized By:	Needham J. Boddie
Attorney Docket Number:	9653-7IPCT
Receipt Date:	12-MAY-2014
Filing Date:	
Time Stamp:	16:19:01
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		9653-7IPCT_PreliminaryAmendment.pdf	538608 bddb58d5a316f33fef0563741d420fbcb6cad503	yes	7

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Preliminary Amendment	1	1
	Abstract	2	2
	Claims	3	6
	Applicant Arguments/Remarks Made in an Amendment	7	7
Warnings:			
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New International Application Filed with the USPTO as a Receiving Office
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PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 14/274,288	Filing Date 05/09/2014	☐ To be Mailed

ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)		
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	05/12/2014	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X $80 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X $420 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	0

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/ANNETTE COWAN/

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 14/274,288

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	280
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	600
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	720
TOTAL CLAIMS (37 CFR 1.16(i))	20 minus 20 =	*			OR	x 80 =	0.00
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3 minus 3 =	*				x 420 =	0.00
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).						0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))							0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	1600

APPLICATION AS AMENDED - PART II

AMENDMENT A

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

AMENDMENT B

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE($)	ADDITIONAL FEE($)		RATE($)	ADDITIONAL FEE($)
Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
Application Size Fee (37 CFR 1.16(s))									
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
					TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
14/274,288	05/09/2014	2878	1600	9653-7IPCT	20	3

CONFIRMATION NO. 9722

20792
MYERS BIGEL SIBLEY & SAJOVEC
PO BOX 37428
RALEIGH, NC 27627

FILING RECEIPT

OC000000068635964

Date Mailed: 05/23/2014

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Steven Francis LeBoeuf, Raleigh, NC;
Jesse Berkley Tucker, Knightdale, NC;
Michael Edward Aumer, Raleigh, NC;
Steven Matthew Just, Cary, NC;

Applicant(s)

Valencell, Inc., Raleigh, NC

Assignment For Published Patent Application

Valencell, Inc., Raleigh, NC

Power of Attorney: The patent practitioners associated with Customer Number 20792

Domestic Priority data as claimed by applicant

This application is a CON of 13/715,247 12/14/2012
which is a CIP of 12/691,388 01/21/2010 PAT 8700111
which claims benefit of 61/208,567 02/25/2009
and claims benefit of 61/208,574 02/25/2009
and claims benefit of 61/212,444 04/13/2009
and claims benefit of 61/274,191 08/14/2009

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.) - None.
Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access - A proper **Authorization to Permit Access to Application by Participating Offices** (PTO/SB/39 or its equivalent) has been received by the USPTO.

If Required, Foreign Filing License Granted: 05/23/2014

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 14/274,288**

Projected Publication Date: 09/04/2014

Non-Publication Request: No

Early Publication Request: No

Title

LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME

Preliminary Class

250

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: No

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific

countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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NOT GRANTED

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/274,288	05/09/2014	Steven Francis LeBoeuf	9653-7IPCT	9722

20792 7590 08/12/2014

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EXAMINER	
FULLER, RODNEY EVAN	
ART UNIT	PAPER NUMBER
2852	

MAIL DATE	DELIVERY MODE
08/12/2014	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 14/274,288	Applicant(s) LEBOEUF ET AL.	
	Examiner RODNEY FULLER	Art Unit 2852	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *05/09/2014*.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *1-20* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *1-20* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *05/09/2014* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☒ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date *05/09/2014*.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

4) ☐ Other: _____.

DETAILED ACTION

1. The present application is being examined under the pre-AIA first to invent provisions.

Claim Rejections - 35 USC § 102

2. The following is a quotation of the appropriate paragraphs of pre-AIA 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

3. Claims 1, 2, 7-10 and 20 are rejected under pre-AIA 35 U.S.C. 102(b) as being anticipated by Aceti (US 7,107,088).

Regarding claims 1 and 20, Aceti discloses "a housing (Fig. 2, ref.# 202, 212); at least one optical emitter (Fig. 2, ref.# 228) supported by the housing; at least one optical detector (Fig. 2, ref.# 238) supported by the housing; a first light guide (Fig. 2, ref.# 232, 236, 224a) supported by the housing, wherein the first light guide is in optical communication with the at least one optical emitter (Fig. 2, ref.# 228), wherein the first light guide comprises a distal end, and wherein the first light guide is configured to deliver light from the at least one optical emitter into a body of the subject via the distal end thereof (See Fig. 2); and a second light guide (Fig. 2, ref.# 242, 224b) supported by the housing, wherein the second light guide is in optical communication with the at least one optical detector (Fig. 2, ref.# 238), wherein the second light guide comprises a distal end, and wherein the second light guide is configured to collect light from the body

of the subject via the distal end thereof and deliver collected light to the at least one optical detector (See Fig. 2)."

Regarding claim 2, Aceti discloses "wherein the housing is configured to be integrated within an audio headset, a wrist strap, a wrist watch, an ankle bracelet, or an armband." (column 1, lines 35-37: finger, ear, foot)

Regarding claim 7, Aceti wherein at least one of the first and second light guides comprises elastomeric light transmissive material." (Fig. 2, ref.# 224a, 224b; column 4, lines 31-35))

Regarding claim 8, Aceti discloses "wherein at least one of the first and second light guides comprises substantially rigid light transmissive material." (Fig. 2, ref.# 232, 242: fibers, i.e., rigid)

Regarding claim 9, Aceti discloses "wherein the at least one optical emitter (Fig. 2, ref.# 228) comprises optical coupling material (Fig. 2, ref.# 232, 236), and wherein the first light guide (Fig. 2, ref.# 224a) is in optical communication with the at least one optical emitter via the optical coupling material."

Regarding claim 10, Aceti discloses "wherein the at least one optical detector (Fig. 2, ref.# 238) comprises optical coupling material (Fig. 2, ref.# 242), and wherein the second light guide (Fig. 2, ref.# 224b) is in optical communication with the at least one optical detector via the optical coupling material."

Claim Rejections - 35 USC § 103

4. The following is a quotation of pre-AIA 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

5. Claims 3, 4, 11-13 and 16-19 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Aceti (US 7,107,088) in view of Oh, et al. (US 8,055,319).

Regarding claims 3, 4, 11 and 12, Aceti discloses all the structure set forth in the claims except (Claim 3) “at least one motion sensor supported by the housing, wherein the at least one motion sensor is configured to sense motion information from the subject”, (Claim 4) “at least one processor supported by the housing, wherein the at least one processor is configured to remove motion artifacts from signals produced by the at least one optical detector in response to signals produced by the at least one motion sensor”, (Claim 11) “at least one processor supported by the housing, wherein the at least one processor is configured to process signals produced by the at least one optical detector) and (Claim 12) “a motion sensor supported by the housing, wherein the motion sensor is configured to sense motion information from the subject; and a processor supported by the housing, wherein the processor is configured to remove motion artifacts from signals produced by the at least one optical detector in response to signals produced by the motion sensor”. However, the use of a motion sensor and associated processor to determine and compensate for noise produced by motion of a user was well known in the art at the time the invention was made as evident from the teaching of Oh (See column 2, lines 60-67). Thus, it would have been obvious to one of ordinary skill in the art at the time the invention was made to modify Aceti by including a

motion sensor and associated processor to remove noise due to motion and improve the accuracy of the measurements.

Regarding claim 13, Aceti discloses “wherein the housing is configured to be integrated within an audio headset, a wrist strap, a wrist watch, an ankle bracelet, or an armband.” (column 1, lines 35-37: finger, ear, foot)

Regarding claim 16, Aceti discloses “wherein at least one of the first and second light guides comprises elastomeric light transmissive material.” (Fig. 2, ref.# 224a, 224b; column 4, lines 31-35))

Regarding claim 17, Aceti discloses "wherein at least one of the first and second light guides comprises substantially rigid light transmissive material.” (Fig. 2, ref.# 232, 242: fibers, i.e., rigid)

Regarding claim 18, Aceti discloses "wherein the at least one optical emitter (Fig. 2, ref.# 228) comprises optical coupling material (Fig. 2, ref.# 232, 236), and wherein the first light guide (Fig. 2, ref.# 224a) is in optical communication with the at least one optical emitter via the optical coupling material.”

Regarding claim 19, Aceti discloses “wherein the at least one optical detector (Fig. 2, ref.# 238) comprises optical coupling material (Fig. 2, ref.# 242), and wherein the second light guide (Fig. 2, ref.# 224b) is in optical communication with the at least one optical detector via the optical coupling material.”

6. Claims 5, 6, 14 and 15 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Aceti (US 7,107,088) in view of Uchida, et al. (US 6,078,829).

Aceti discloses all the structure set forth in the claims except (Claims 5 and 14) "wherein the first light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by first light guide" and (Claim 6 and 15) "wherein the second light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by second light guide." However, the use of filters (i.e., optical dyes to filter wavelengths) with optical systems that measure biological information (i.e., reflectance from blood) was well known in the invention was made as evident from the teaching of Uchida (See columns 5-6). Thus, it would have been obvious to one of ordinary skill in the art at the time the invention was made to modify Aceti by including optical dye (i.e., filters) with the light guides in order to selectively choose wavelength (i.e., specific bands) in order to accurately determine information such as blood sugar, oxygen content, etc.

Double Patenting

7. The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory double patenting rejection is appropriate where the claims at issue are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir.

1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the reference application or patent either is shown to be commonly owned with this application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement. A terminal disclaimer must be signed in compliance with 37 CFR 1.321(b).

The USPTO internet Web site contains terminal disclaimer forms which may be used. Please visit http://www.uspto.gov/forms/. The filing date of the application will determine what form should be used. A web-based eTerminal Disclaimer may be filled out completely online using web-screens. An eTerminal Disclaimer that meets all requirements is auto-processed and approved immediately upon submission. For more information about eTerminal Disclaimers, refer to http://www.uspto.gov/patents/process/file/efs/guidance/eTD-info-I.jsp.

8. Claims 1-20 are rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-30 of U.S. Patent No. 8,788,002. Although the claims at issue are not identical, they are not patentably distinct from each other.

9. Claims 1-20 are rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-42 of U.S. Patent No. 8,700,111. Although the claims at issue are not identical, they are not patentably distinct from each other.

10. Claims 1-20 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-20 of copending Application No. 14,298,219. Although the claims at issue are not identical, they are not patentably distinct from each other.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

11. Claims 1-20 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-21 of copending Application No. 14,298,402. Although the claims at issue are not identical, they are not patentably distinct from each other.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

12. Claims 1-20 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-42 of copending Application No. 14184364. Although the claims at issue are not identical, they are not patentably distinct from each other.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

13. Claims 1-20 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1-20 of copending Application No. 14,194,891. Although the claims at issue are not identical, they are not patentably distinct from each other.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

14.

Conclusion

15. The prior art made of record and not relied upon is considered pertinent to applicant's disclosure:

a. Uchida, et al. (US 2003/0109030)

b. Kraus, et al. (US 6,358,216)

16. Any inquiry concerning this communication or earlier communications from the examiner should be directed to RODNEY FULLER whose telephone number is (571)272-2118. The examiner can normally be reached on 8:00am - 4:30pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Clayton Laballe can be reached on 571-272-1594. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/RODNEY FULLER/
Primary Examiner, Art Unit 2852

August 7, 2014

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	Examiner RODNEY FULLER	Art Unit 2852	Page 1 of 1

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	K	US-			
	L	US-			
	M	US-			

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*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
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*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14274288	LEBOEUF ET AL.
	Examiner	Art Unit
	RODNEY FULLER	2852

CPC- SEARCHED		
Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
600	310	8/7/2014	/RF/

SEARCH NOTES		
Search Notes	Date	Examiner
East text search history printout	8/7/2014	/RF/
600/310, 322, 323, 324 (w/ text search)	8/7/2014	/RF/
CPC w/ text search	8/7/2014	/RF/

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

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CONFIRMATION NO. 9722

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
14/274,288	05/09/2014 RULE	600	2852	9653-7IPCT

APPLICANTS

Valencell, Inc., Raleigh, NC, Assignee (with 37 CFR 1.172 Interest);

INVENTORS

Steven Francis LeBoeuf, Raleigh, NC;
Jesse Berkley Tucker, Knightdale, NC;
Michael Edward Aumer, Raleigh, NC;
Steven Matthew Just, Cary, NC;

**** CONTINUING DATA **************************

This application is a CON of 13/715,247 12/14/2012 PAT 8788002
which is a CIP of 12/691,388 01/21/2010 PAT 8700111
which claims benefit of 61/208,567 02/25/2009
and claims benefit of 61/208,574 02/25/2009
and claims benefit of 61/212,444 04/13/2009
and claims benefit of 61/274,191 08/14/2009

**** FOREIGN APPLICATIONS **************************

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****

05/23/2014

Foreign Priority claimed	35 USC 119(a-d) conditions met	Verified and Acknowledged	Met after Allowance	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
☐ Yes ☑ No	☐ Yes ☑ No	/RODNEY EVAN FULLER/ Examiner's Signature	☐ Initials	NC	28	20	3

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PO BOX 37428
RALEIGH, NC 27627
UNITED STATES

TITLE

LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME

FILING FEE RECEIVED		
1600	FEES: Authority has been given in Paper No._____ to charge/credit DEPOSIT ACCOUNT No._____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

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EAST Search History

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Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
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				Application Number	To Be Assigned
				Filing Date	Concurrently Herewith
				First Named Inventor	Steven Francis LeBoeuf
				Art Unit	
				Examiner Name	
Sheet	A1	of	A2	Attorney Docket Number	9653-7IPCT

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Examiner Signature	/Rodney Fuller/	Date Considered	08/06/2014

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /RF/

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (use as many sheets as necessary)				Complete if Known	
				Application Number	To Be Assigned
				Filing Date	Concurrently Herewith
				First Named Inventor	Steven Francis LeBoeuf
				Art Unit	
				Examiner Name	
Sheet	A2	of	A2	Attorney Docket Number	9653-7IPCT

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Examiner Signature	/Rodney Fuller/	Date Considered	08/06/2014

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT *(use as many sheets as necessary)* Sheet 1 of 1	*Complete if Known*	
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	Filing Date	05-09-2014
	First Named Inventor	Steven Francis LeBoeuf
	Art Unit	2852
	Examiner Name	Rodney Evan Fuller
	Attorney Docket Number	9653-7IPCT

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Examiner Initials*	Cite No.	Document Number Number-Kind Code (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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Examiner Initials*	Cite No.	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published	T

Examiner Signature		Date Considered	

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A61B 5/024 (2006.01) *A61B 5/11* (2006.01)

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(71) Applicant *(for all designated States except US)*: **KONINKLIJKE PHILIPS ELECTRONICS N.V.** [NL/NL]; High Tech Campus 5, NL-5656 AE Eindhoven (NL).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **PRESURA, Cristian Nicolae** [NL/NL]; c/o High Tech Campus Building 44, NL-5656 AE Eindhoven (NL). **ROOVERS, David, Antoine, Christian, Marie** [NL/NL]; c/o High Tech Campus Building 44, NL-5656 AE Eindhoven (NL).

(74) Agents: **COOPS, Peter** et al.; High Tech Campus, Building 44, NL-5656 AE Eindhoven (NL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

— *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*

Published:

— *with international search report (Art. 21(3))*

(54) **Title**: DEVICE AND METHOD FOR ESTIMATING THE HEART RATE DURING MOTION

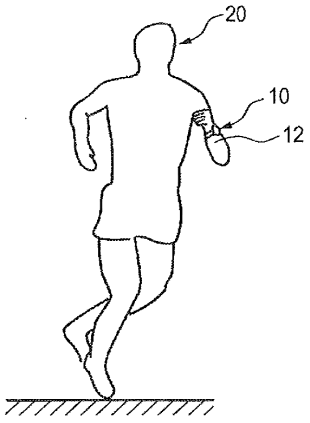

Fig. 1

(57) **Abstract**: The present invention relates to a portable device (10) for determining a heart rate of a person (20), comprising a heart rate measurement unit, a motion measurement unit for measuring the motion of a body part (12), and a processing unit. The processing unit is adapted to measure a signal quality of the heart rate signal and accordingly switch between two calculation modes: If the signal quality is above a predefined threshold, the heart rate is calculated based on the heart rate signal. If the signal quality is so poor that a reliable calculation of the heart rate is technically not possible anymore based on the heart rate signal, the processing unit switches to its second calculation mode, in which the heart rate is estimated based on the motion signal by estimating a heart rate constant, which depends on the frequency of the motion signal, and defining an exponential development of the heart rate, starting at the last reliably measured heart rate and finishing at the estimated heart rate constant.

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Device and method for estimating the heart rate during motion

FIELD OF THE INVENTION

The present invention relates to a portable device for determining the heart rate of a person. The invention further relates to a corresponding method and a system. Even further, the present invention relates to a computer program for controlling said device to carry out the steps of said method.

BACKGROUND OF THE INVENTION

Due to the growing number of people that live an inactive life, many physical activity promotion products and services have been developed over the last decades, both for research and commercial objectives. Said physical activity promotion products in most cases try to calculate or estimate the heart rate in order to display the person's pulse during a physical activity. At present, the most successful devices that measure the heart rate for athletes make use of a chest belt. These devices measure the electric signal of the heart (ECG) during the athlete's physical activity. However, these chest straps are uncomfortable to wear, which practically restricts their use to serious athletes.

Because more and more people are aware of the power of monitoring heart rate for their health, and most people try to avoid wearing such a kind of chest strap due to its uncomfortableness, the paradigm of measuring a heart rate slowly changes from high resolution and low comfort to medium resolution but higher wearing comfort.

This is achieved, for example, through optical heart rate monitors, which may be attached to different parts of the body, e.g. also to the wrist of the athlete. A device of this kind, which is known from the prior art, is commercially distributed under the name ePulse2™. This heart rate monitor includes an optical sensor that is similar to pulse oximeters available in the market. It is realized as an arm band that can be worn conveniently on the wrist.

Optical sensors used for heart rate measurement, however, suffer from large movement artifacts, especially in case of large and fast movements as these occur during a physical activity like running, cycling or rowing. That is because the optical sensor in fact optically measures the blood flow inside the blood vessel, which blood flow is, of course,

also influenced by the body movement, so that discontinuous, rough movements occur within the blood vessel. This results in large movement artifacts, which complicate the heart rate measurement.

For this reason, some optical sensors known from the prior art use an additional motion sensor to measure the occurring motion of the body part and to compensate for the resulting motion artifacts. However, there is a limit. When the movement of the body part, to which the sensor is attached, becomes very large, the optical sensor does not provide reliable measurements anymore, even when the measurement signal is compensated, respectively adapted with the motion signal provided from the motion sensor.

In this case, the heart rate monitor either displays a wrong heart rate value or no heart rate value at all. This is regarded to be a major disadvantage, since the measurement results in an inaccurate or no displayed heart rate.

Several years of experience with a large set of users have shown that participants attach high importance to the reliability and the comfort of such heart rate measurements. In particular, when athletes or sportsmen have engaged in heavy activity or exercise they consider it necessary to have a reliable, real time feedback of the current heart rate at all times. If the heart rate monitor has registered a wrong heart rate or does not even display a value of the heart rate, this can be experienced as de-motivating and has a negative impact on the overall perception of the device.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a device, a method, a system and a corresponding software of the kind mentioned initially, which enable an improved heart rate measurement, wherein the heart rate is measured in a comfortable way for the user and the measurement still delivers reliable measurement results even when strong motions occur at the measured body part of the user. It is in particular an object of the present invention, to calculate or estimate the heart rate to the largest degree of accuracy and to overcome the problem of large movement artifacts within the heart rate signal that may lead to a failure of the heart rate measurement.

In a first aspect, this object is according to the present invention achieved by a portable device for determining a heart rate of a person, said portable device comprising:

- a heart rate measurement unit for measuring the heart rate of the person over time to generate a heart rate signal,

- a motion measurement unit for measuring the motion of a body part of the person over time to generate a motion signal, and
- a processing unit which is adapted to measure a signal quality of the heart rate signal, to calculate the heart rate based on the heart rate signal if said signal quality is above a predefined threshold, and to estimate the heart rate based on the motion signal if said signal quality is below said threshold.

In a second aspect of the present invention, a corresponding method is presented, which includes the steps of:

- measuring the heart rate of the person over time to generate a heart rate signal,
- measuring the motion of a body part of the person over time to generate a motion signal,
- measuring a signal quality of the heart rate signal, and
- calculating the heart rate based on the heart rate signal if said signal quality is above a predefined threshold, and estimating the heart rate based on the motion signal if said signal quality is below said threshold.

In a third aspect of the present invention, a system for determining a heart rate of a person is presented, said system comprising:

- a portable heart rate measurement device for measuring the heart rate of the person over time to generate a heart rate signal,
- a portable motion measurement device for measuring the motion of a body part of the person over time to generate a motion signal, and
- a processing device which comprises a communication interface for receiving said heart rate signal and said motion signal, and a processing means which is adapted to measure a signal quality of the heart rate signal, to calculate the heart rate based on the heart rate signal if said signal quality is above a predefined threshold, and to estimate the heart rate based on the motion signal if said signal quality is below said threshold.

In a still further aspect of the present invention, a computer program product is presented comprising program code means for causing a computer to control said portable device to carry out the steps of said method when said computer program is carried out on the computer.

Preferred embodiments of the invention are defined in the dependent claims. It shall be understood that the claimed method and the claimed system have similar and/or identical preferred embodiments as the claimed portable device and as defined in the dependent claims.

It has been recognized by the inventors that the heart rate may still be estimated in a reliable manner even when the heart rate signal, which is generated by the heart rate measurement unit, becomes unreliable due to movement artifacts. According to the invention, the heart rate is in such cases estimated based on the motion signal that is provided by the motion measurement unit. Estimating the heart rate based on the motion signal means that the heart rate is estimated based on at least the motion signal, which again means that also other parameters and signals may be included into this estimation. In order to implement this kind of heart rate measurement, the processing unit is adapted to measure the signal quality of the heart rate signal. In case the heart rate signal is above a predefined threshold value, the heart rate may be measured based on the heart rate signal. This may be done by a frequency evaluation of the heart rate signal, which results in a determination of the pulse of the person.

If on the other hand, the signal quality of the heart rate signal is detected to be below said predefined threshold, the heart rate may be estimated based on the motion signal. Thereto, the processing unit is adapted to switch from a first mode, in which the heart rate is calculated from the measured heart rate signal, to a second mode, in which the heart rate is estimated based on the measured motion signal. The switch between these two modes depends on the threshold value.

Said threshold value indicates a level of noise within the heart rate signal, wherein the heart rate signal measured by the heart rate measurement unit becomes unreliable when exceeding a certain level of noise, respectively when under-running said threshold. In other words, said threshold value indicates a minimum signal quality of the heart rate signal that is needed to reliably calculate the heart rate based on the heart rate signal. The threshold value may be determined from experiments that evaluate at what level of motion of the device the movement artifacts, that are induced into the heart rate signal, become so large or strong, that a reliable measurement of the heart rate cannot be extracted simply from the heart rate signal anymore. This threshold or threshold level of noise does not necessarily need to be an exact value. It may also be a range of values where the signal quality of the heart rate signal transitions from a good or sufficient measurement quality to a low, insufficient measurement quality. In still other words, the threshold value indicates the lowest possible signal quality level of the heart rate signal, below which a calculation of the heart rate based on the heart rate signal would lead to a failure, respectively to a wrong heart rate value that is outside a tolerable failure range.

By making use of the motion signal, it is possible to reliably estimate the heart rate, also in cases in which the heart rate signal is unusable due to large motion artifacts. This is a major advantage compared to the devices of the prior art mentioned initially, since the user receives a reliable feedback of its heart rate/pulse, even in cases where the device is subjected to high accelerations or strong vibrations.

In contrast to the prior art devices, the presented portable device thus allows to provide a heart rate to the user at all times, even in instances, in which the heart rate measurement unit fails.

Estimating the heart rate based on the motion signal does not necessarily mean that the motion signal, only, is taken into account to estimate the heart rate. Even in the above-mentioned cases, in which the signal quality of the heart rate signal is below the predefined threshold, the heart rate signal may still be taken into account. In such an embodiment the processing unit is adapted to correct, respectively adapt the heart rate signal based on the information taken from the motion signal. In other words, the heart rate signal is in this case corrected with correction values that may be determined from the motion signal, e.g. filtering the noise that occurs within the heart rate signal by comparing/substracting the motion induced signal parts from the heart rate signal.

Even though the heart rate may be directly calculated from the heart rate signal if the signal quality of the heart rate signal is above said predefined threshold, the processing unit may, according to an embodiment of the invention, be adapted to calculate the heart rate based on the heart rate signal and to adapt the calculated heart rate based on the motion signal. However, this is not necessarily needed when the heart rate can be measured in a reliable manner. Nevertheless, this measure can be implemented as a further improvement of the heart rate measurement.

According to the invention, the heart rate measurement unit can be realized by any kind of sensor that enables to measure the heart rate of a person over time. This may also include an electrical ECG electrode. According to a preferred embodiment of the present invention the heart rate measurement unit comprises an optical sensor, in particular a photoplethysmography (PPG) sensor for measuring a blood pulse wave of the person over time to generate the heart rate signal. The PPG sensor includes a photo detector that, in the normal way, measures the absorbance of the blood at different wavelengths allowing a determination of the light absorbance due to the pulsing arterial blood.

Such a kind of PPG sensor enables to measure the pulse of the person in a comfortable way. The portable device may, for example, be attached to the wrist of the

person. In contrast to known PPG sensors that are usually attached to the fingertip or the earlobe of the person, an attachment on the wrist of the person allows an appliance of the portable device for different kinds of sport activities, wherein the device may comfortably be worn. Even though an attachment on the wrist is preferred, the portable device may also be attached to any other body part of the person, e.g. the chest, a leg or around the neck.

The above-mentioned motion measurement unit preferably comprises an inertial sensor for measuring an acceleration of the body part to which it is attached in at least one spatial dimension. This inertial sensor is preferably adapted to perform a three-axial accelerometry. Thereto, it is preferably equipped with three accelerometers and/or three gyroscopes. The accelerometers are placed such that their measuring axes are perpendicular to each other, in order to being able to measure the G-forces in all three spatial dimensions. The three gyroscopes are placed in a similar perpendicular pattern, which enables to measure the rotational position of the device in reference to an arbitrarily chosen coordinate system. It is to be understood that the gyroscopes are not necessarily needed, since the accelerometers measuring the acceleration in the different spatial directions are sufficient for the most appliances. Further, it is to be noted that a single accelerometer is also sufficient to generated the desired motion/acceleration signal.

The portable device is preferably designed in a shape that is similar to a watch. According to an embodiment of the present invention, the portable device comprises a display for displaying the calculated heart rate. This display enables to provide the user with the measured heart rate/pulse in real time. This display may be realized in different ways, e.g. as an LED array.

According to an embodiment of the present invention, the processing unit is adapted to determine the signal quality of the heart rate signal in the frequency domain by analyzing the spectral peaks of the heart rate signal at the heart rate frequency and/or its harmonics.

In this analysis the height, respectively the magnitude of these peaks is investigated. This gives an indication of the signal power of the heart rate signal. In general, it can be stated that the higher and the clearer the peaks are developed in the frequency domain, the better is the signal quality of the heart rate signal. This mainly relies on the fact that the blood pulse wave ideally generates a periodic signal, which in the frequency domain results in clear peaks at or near the heart rate frequency and/or its harmonics.

A clear peak at the heart rate frequency and/or its harmonics is thus an indicator for a periodic signal, which again is an indicator for a good signal quality of the

heart rate signal. If, on the other hand, the heart rate signal is corrupted by the occurring motion and includes motion artifacts, this will result in different noisy peaks within the power spectrum. Generally speaking, the signal quality can thus be determined based on the spectral peaks of the heart rate signal.

If clear peaks occur at or around the heart rate frequency and/or its harmonics, the signal quality is reliable enough to calculate the heart rate based on the heart rate signal (first mode). If on the other hand, the spectral analysis of the heart rate signal shows a noisy spectrum, the processing unit switches to the second mode, in which the heart rate is estimated based on the motion signal.

In an embodiment, the portable device further comprises a frequency filter to filter out the frequency components within the heart rate signal which are due to motion of the device, wherein the processing unit is adapted to determine the signal quality of the filtered heart rate signal. This filter enables an easier detection of the heart rate from the heart rate signal. However, this is not a necessary feature, since in practice the frequency components which are due to motion occur at different frequencies than the frequency components that are due to the heartbeat. In practice, it is thus in most cases possible to clearly distinguish between the different kinds of frequency components, especially when analyzing the heart rate signal in the frequency domain.

Instead of analyzing the heart rate signal in the frequency domain, the processing unit may also be adapted to determine the signal quality of the heart rate signal in the time domain by analyzing the height of the peaks in the autocorrelation function at the heart rate period and its multiples. In case of analyzing the heart rate signal in the time domain, the processing unit measures the level of signal quality depending on the periodic components within the signal, which again are an indicator for a reliable heart rate signal. This may, for example, be done by counting the zero crossings and/or the signal peaks, or by analyzing the consistency of the signal peaks. Similarly as mentioned above, the processing unit then decides, depending on the signal analysis, if the heart rate is calculated based on the heart rate signal (first mode), or if the heart rate is estimated based on the motion signal (second mode).

The estimation of the heart rate based on the motion signal in the second working mode of the processing unit is preferably done as follows:

According to an embodiment of the present invention, the processing unit is adapted to estimate the heart rate based on the motion signal by estimating a heart rate constant ($HR_{constant}$) and defining an exponential development of the heart rate over time,

wherein the exponential development of the heart rate starts at the last reliably measured heart rate and finishes at the estimated $HR_{constant}$. The $HR_{constant}$ is an estimated heart rate of the person which depends on the frequency of the motion signal, and the last reliably measured heart rate is the last measured heart rate with the heart rate measurement unit at a point in time before under-running said level of signal quality.

The processing unit thus estimates the heart rate in two steps. In a first step, $HR_{constant}$ is estimated. The estimation of the $HR_{constant}$ requires an estimation of the present motion, respectively an estimation of the frequency of the device motion (the frequency of the motion of the measured body part). This frequency can be derived from the measured motion signal.

The $HR_{constant}$ indicates a pulse level of the person to which the person's pulse would increase or decrease if the amount and intensity of motion would be kept constant for a long time. In other words, the estimation is based on the assumption that the person's movement is kept constant during the so-called transition period, in which the device switches to the second mode, in which the heart rate is estimated based on the motion signal. Since the transition period in practice is only a very short time period of several seconds, this assumption has shown to result in a good approximation.

Once the $HR_{constant}$ is determined, the processing unit defines an exponential development of the heart rate over time with a start value at the last reliably measured heart rate that has been measured based on the heart rate signal and a terminal value that equals the $HR_{constant}$. It has been shown that an exponential development reflects the natural behavior of the human heart in a good and precise manner.

This exponential behavior is an approximation curve for a person's pulse in-/decrease. This in-/decrease also depends on the physical fitness of the person. The exponential approximation curve thus preferably has a time constant a, wherein a being a constant related to the person's fitness which decreases with increasing fitness.

According to an embodiment of the present invention the processing unit is adapted to calculate the $HR_{constant}$, with $HR_{constant} = 2{,}1 * f - a$, where f is the frequency of the motion signal, and a is the constant indicating the person's fitness with $a = 75 - HR_{rest}$, and HR_{rest} being the resting heart rate of the person.

It is to be noted, that the above relation between the $HR_{constant}$ and the intensity of the person's physical activity, which is indicated by the motion frequency of the measured body part, is a linear relation. This relation has been found on the basis of experiments that have been performed by the applicant. These experiments have shown that the $HR_{constant}$ stays

at a value that is about two times the motion frequency. A good approximation for the fitness parameter a has been found to be $a = 75 - HR_{rest}$.

The resting heart rate HR_{rest} may, for example, be measured directly using the presented portable device measuring the heart rate, when the user rests, i.e. when the user is not moving. Furthermore, the HR_{rest} may also be estimated from the heart rate signal during the regular heart rate measurement (in the first working mode of the processing unit). However, it is to be noted that also other values can be chosen for a, HR_{rest} and $HR_{constant}$ without leaving the scope of the invention.

Instead of measuring or estimating the HR_{rest}, it is also conceivable that the portable device comprises an input interface, that may for example be realized as a small key pad or touch pad that enables the user to manually type in his/her HR_{rest}. In this way, it is also conceivable that the user directly defines his/her personal fitness parameter a.

Instead of manually defining the fitness parameter a and measuring the motion frequency f, a much better method to determine the $HR_{constant}$ is to use previous measurement sessions of the same user.

According to an embodiment of the present invention, the portable device further comprises a storage unit which is adapted to store reference measures for heart rates belonging to known levels of intensity of the person's physical activity, wherein the processing unit is adapted to determine a level of intensity of the person's physical activity based on the generated motion signal, and to determine the heart rate constant ($HR_{constant}$) by comparing the determined level of intensity with the reference measures stored in said storage unit if the signal quality of the heart rate signal is below the threshold signal quality.

Said reference measures may be heart rate measurements that have been recorded from previous measurement sessions of the same user. If the user has performed a physical activity, such as e.g. running a day before using the same portable device, then the measured signals can be stored in the storage unit. By recording the heart rate signal together with the corresponding motion signal the calculated heart rates may be mapped/linked to the corresponding motion levels that are derived from the motion signal.

In this way, it is also possible to determine different heart rate constants that correspond to different levels of intensity of the person's physical activity using the previous measurements. For example, it is conceivable that a certain amount of intensity levels are mapped within the storage unit to corresponding heart rate constants. In this case, not necessarily all previous measurement data need to be stored in the storage unit.

The level of intensity of the person's physical activity may, for example, be determined based on the frequency, at least one peak value of the generated motion signal and/or based on the average level or amplitude of the generated motion signal over a time-interval. The level of intensity thus indicates a motion level, which is a measure for the physical load the person is subjected to during his/her physical activity.

The storage unit may, for example, be realized by a small microchip. The recording of the reference heart rates or reference heart rate constants can be performed automatically. Thereto, the processing unit switches to a recording mode, in which the processed heart rates and the corresponding motion intensity levels are concurrently stored in the storage unit during the measurement. Determining the heart rate constant based on stored reference measures, as this has been explained above, results in increased measurement efficiency. The user does no longer need to manually type in the parameters that are used to calculate the $HR_{constant}$ (parameters a, f).

A personalized $HR_{constant}$ may be determined in an efficient way by analyzing the previous recorded data. The deduced parameters are in this way personalized, so that their usage improves the future estimations of the heart rate in the transition periods, in which the processing unit switches to the second working mode.

According to a further embodiment of the present invention, the portable device further comprises a first input interface for receiving information about a type of physical activity of the person, wherein the processing unit is adapted to estimate the heart rate based on the motion signal and the type of physical activity if the signal quality of the heart rate signal is below said level of signal quality.

This first input interface may, for example, be realized as a small key pad that is integrated into the portable device. In this way, the user may manually select a type of physical activity he wants to perform. The user may, for example, be shown a selection list of different physical activities, such as e.g. running, cycling, rowing, weightlifting, etc.

If the type of physical activity is known in advance, this simplifies the determination of the motion frequency, since each type of physical activity in practice generates a different kind of pattern of the detected motion signal with a different expected average motion frequency. Having at least rough information about the expected motion frequency enables to safe processing time in the second mode of the processing unit in which the heart rate is estimated based on the motion signal.

The information about the type of physical activity may also allow to adapt the above-mentioned exponential approximation curve within the transition period. This meets

the fact that the heart rate may have a different development over time for different kinds of physical activities, e.g. the heart rate may in-/decrease faster in a cycling activity compared to a weightlifting activity.

According to a further embodiment of the present invention, the portable device comprises a second input interface for receiving the person's personal data, in particular an age, a gender, a body weight, a body height and/or a resting heart rate, wherein the processing unit is adapted to estimate the heart rate based on the motion signal and the received personal data if the signal quality of the heart rate signal is below the above-mentioned threshold signal quality.

Instead of determining the personalized parameters from previous measurements as this has been explained above, it is also conceivable that the user manually enters his/her personal data that physiologically influence the heart rate and its development over time. Said second input interface may either be an extra key pad or realized by the same key pad that is used as first input interface.

The personal physiological user data may be either used to adapt the above-mentioned parameters to calculate the $HR_{constant}$ or they may be used to apply an additional physiological model, which model can then be used to adapt the above-mentioned heart rate development model during the transition period. Examples of such kind of physiological models are known from the prior art. Some exemplary models are, for example, known from the scientific paper "Reliability and Validity of the Combined Heart Rate and Movement Sensor Actiheart", European Journal of Clinical Nutrition (2005) 59, 561-570.

In summary, the presented portable device and the corresponding method allow to detect the heart rate of an athlete or a sportsman in many different situations, even in situations where large movements occur and state of the art optical heart rate sensors are not able to reliably detect the heart rate. As explained in the foregoing, the processing unit is adapted to switch between two modes. In the first mode, the heart is calculated based on the heart rate signal if the signal quality is above a predefined threshold. If on the other hand, the processing unit is not able to reliably calculate the heart rate based on the heart rate signal, the processing unit switches to a second mode in which the heart rate is estimated from motion, by using a model in which the data is compared with a set of values determined from previous measurements or introduced as input by the user. The presented method thereby makes use of one of the following features, or any combination thereof:

1. The history of the good measurements up to the point of failure,

2. an indication of the quality of the measurements made, which tells that the last measurement is a failure,

3. a profile of the user that can be either be pre-recorded or determined from the reliable measurements, and/or

4. a physiological model that makes use of parameters that are determined from previous measurements from the same user.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiment(s) described hereinafter. Therein:

Fig. 1 shows a schematic appliance of a portable device according to the present invention,

Fig. 2 shows a schematic block diagram illustrating the components of the portable device according to a first embodiment,

Fig. 3 shows a schematic block diagram illustrating in- and output signals of a processing unit of the portable device according to the first embodiment,

Fig. 4 shows a schematic block diagram illustrating the components of the portable device according to a second embodiment,

Fig. 5 shows a first example of a measured heart rate signal (Fig. 5a) including a corresponding signal quality measurement (Fig. 5b),

Fig. 6 shows a second example of a measured heart rate signal (Fig. 6a) including a corresponding signal quality measurement (Fig. 6b),

Fig. 7 shows a third example of a measured heart rate signal (Fig. 7a) including a corresponding signal quality measurement (Fig. 7b),

Fig. 8 shows the first example shown in Fig. 5 including a heart rate signal that has been estimated with the presented portable device according to the presented method,

Fig. 9 shows the second example shown in Fig. 6 including a heart rate signal that has been estimated with the presented device according to the presented method,

Fig. 10 shows the third example shown in Fig. 7 including a heart rate signal that has been estimated with the presented device according to the presented method,

Fig. 11 schematically shows an appliance of a system according to the present invention, and

Fig. 12 shows an exemplary diagram illustrating a relation between the heart rate and the power/intensity of a physical exercise.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 schematically shows an appliance of the portable device according to the present invention which is denoted by the reference numeral 10. A person 20, that is in this figure exemplarily shown as a runner, wears the portable device 10 for measuring the pulse during his/her physical activity.

The portable device 10 is attached to a body part 12, which body part 12 is suitable for measuring the pulse of the person 20, i.e. a body part 12 on which the arterial blood pulse can easily be tracked. As shown in Fig. 1, the portable device is preferably attached to the wrist of the person 20. However, the portable device may also be attached to any other body part 12 of the person 20, e.g. the chest, a leg or around the neck.

As this is shown in the schematic block diagram of Fig. 2 said portable device comprises a heart rate measurement unit 14, a motion measurement unit 16 and a processing unit 18. The heart rate measurement unit 14 and the motion measurement unit 16 are electronically coupled with the processing unit 18. The heart rate measurement unit 14 preferably comprises an optical sensor, in particular a photoplethysmography (PPG) sensor, which measures the blood pulse wave of the person 20 over time and generates a heart rate signal 22.

The PPG sensor includes a photodetector (not shown) that measures the absorbance of the blood at different wavelengths allowing a determination of the light absorbance changes that are due to the pulsing arterial blood. Such a kind of PPG sensor allows measuring the pulse of the person in a comfortable way.

The motion measurement unit 16 preferably comprises an inertial sensor for measuring an acceleration of said body part 12 in at least one spatial dimension, more preferably in all three spatial dimensions. This inertial sensor measures the motion of said body part 12 of the person 20 over time to generate an acceleration-over-time signal that records the occurring accelerations at the wrist of the person 20 to which the portable device 10 is preferably attached.

In this way, the processing unit 18 receives two signals that are measured in real time, the heart rate signal 22 and the motion signal 24. This is exemplarily shown in the illustrated block diagram of Fig. 3. The processing unit 18 analyzes the heart rate signal 22 and the motion signal 24. From this analysis the processing unit 18 calculates the heart rate 26 and the motion rate 28, wherein the motion rate 28 indicates the motion frequency with which the body part 12 is moved during the physical activity of the person 20.

The processing unit 18 further measures a signal quality 30 of the heart rate signal 22 and a signal quality 32 of the motion/acceleration signal 24. The signal quality 30, 32 indicates a measure for the data reliability of the measured signals 22, 24. It indicates the amount of noise that corrupts the measured signals 22, 24. A low noise corruption leads to a high signal quality 30, 32, whereas a high noise corruption leads to a correspondingly low signal quality 30, 32. The amount of noise corruption within the measured signals 22, 24 is measured in the processing unit 18 by performing a frequency analysis, as this has been explained in detail in the summary of the invention above.

Depending on the signal quality 30 of the heart rate signal 26 the processing unit 18 switches between two calculation modes. Thereto, a threshold is defined, said threshold indicating the level of noise within the heart rate signal 22, wherein the heart rate signal 22 that is measured by the heart rate measurement unit 14 becomes unreliable when exceeding said predefined level of noise, respectively when under-running said threshold. Thus, the threshold indicates the minimum signal quality 30 of the heart rate signal 22 that is needed to reliably calculate the heart rate 26 based on the heart rate signal 22.

The processing unit 18 switches to the first calculation mode if the signal quality 30 of the heart rate signal 22 is above said predefined threshold. In this case, the processing unit 18 calculates the heart rate 26 based on the heart rate signal 22. This mode represents the "normal" mode in which the optical sensor of the heart rate measurement unit 14 delivers a reliable signal that includes only a few motion artifacts, which still enables to calculate the heart rate 26 based on the measured heart rate signal 22.

If, however, the portable device 10 is subjected to strong agitations (high accelerations) the signal quality 30 of the heart rate signal 22 may become so poor that a reliable calculation of the heart rate 26 is technically not possible anymore based on the heart rate signal 22. Such situations occur when the person 20 is moving the body part 12 in a fast and discontinuous way.

In such cases devices of the prior art using similar optical heart rate measurement sensors fail to measure the heart rate, which means that no reliable measurement is possible. However, this problem has been solved by the present invention.

In the cases described above, the processing unit 18 is adapted to switch to its second calculation mode, in which the heart rate 26 is estimated based on the motion signal 24. This estimation of the heart rate 26 starts as soon as the processing unit 18 recognizes that the signal quality 30 of the heart rate signal 22 falls below the predefined quality threshold. The processing unit 18 then estimates the heart rate 26 using a physiological model that

makes use of the signal data taken from the motion signal 24. This estimation is, according to an embodiment, done as follows. In a first step, the processing unit 18 estimates an $HR_{constant}$. This $HR_{constant}$ indicates a pulse level of the person to which the person's pulse would increase or decrease if the amount and intensity of motion would be kept constant for a long time.

As it can be seen from the exemplary diagram shown in Fig. 12, there is a linear relation between the heart rate 26 and the power of the effort of a physical exercise. In this diagram, the X-axis shows the speed of a runner measured in kph, the left Y-axis shows the heart rate above sleep in bpm, and the right Y-axis shows the power of the exercise (PAI) expressed in J/min/kg. This plot was made from an experiment with about 30 persons, whose pulse was measured during running with different running speeds and intensity levels. It shows that there is a linear relation between the heart rate and the power/intensity with which the running activity is performed. This plot has been published in 2005 in the European Journal of Clinical Nutrition (2005) 59, 561-570, "Reliability and Validity of the Combined Heart Rate and Movement Sensor Actiheart".

Experiments performed by the applicant have shown that the $HR_{constant}$ more or less equals a value that is about two times the frequency of the motion. Thus, the estimation of the $HR_{constant}$ requires an estimation of the present motion, respectively an estimation of the frequency of the motion of the measured body part 12.

This frequency is derived from a spectral analysis of the motion signal 24. Once the $HR_{constant}$ is determined, the processing unit 18 produces an approximation curve that represents the estimated heart rate development over time for the time period in which the processing unit 18 is switched to the second mode (transition period), in which the optical heart rate sensor 14 does not deliver a reliable signal 22. This approximation curve takes the last reliably measured heart rate 26 as its start value and the estimated $HR_{constant}$ as its terminal value. In between these two values an exponential approximation curve is applied. It has been shown that an exponential development reflects the natural behavior of the human heart in a good and precise manner.

Since the so-called transition period, in which the optical heart rate sensor 14 fails to measure, is in practice only a very short time period of several seconds, this assumption has shown to result in a good approximation. Experiments performed by the applicant have further shown that the described exponential development of the pulse adaption also depends on the fitness of the person 20.

A fitness factor a, which denotes the fitness level of the person 20, is thus preferably integrated in addition. Experiments have shown that an exponential approximation curve, where the time constant is given by the fitness factor a results in a rather good estimation of the heart rate development during the transition period. The fitness factor a in this case denotes a constant related to the person's fitness in such a way, that a decreases with increasing fitness of the person 20.

The estimation of the heart rate development during the transition period may be further improved by taking into account previous measurement sessions of the same user 20. The $HR_{constant}$ may thus be determined based on stored previous measurement data. To implement this, the portable device 10 comprises, according to a second embodiment that is shown in Fig. 4, an additional storage unit 34 which is adapted to store reference measures for heart rates 26 belonging to reference levels of intensity of the person's physical activity. According to this embodiment, the processing unit 18 is adapted to determine a level of intensity of the person's physical activity based on the generated motion signal 24, and to determine the heart rate constant ($HR_{constant}$) by comparing the determined level of intensity with the reference measures stored in said storage unit 34.

Said reference measures may be heart rate measurements that have been recorded from previous measurement sessions of the same user 20. If the user 20 has performed a physical activity, such as e.g. running a day before using the same portable device 10, then the measured signals can be stored in the storage unit 34. By recording the heart rate signal 22 together with the corresponding motion signal 24, the calculated heart rate 26 may be linked to the corresponding motion levels that are derived from the motion signal 24. In this way, the processing unit 18 is enabled to determine different heart rate constants that correspond to different levels of intensity of the person's physical activity using the previous measurements.

The level of intensity of the person's physical activity may, for example, be determined based on the frequency, at least one peak value of the generated motion signal 24 and/or based on the average level or amplitude of the generated motion signal 24 over a time interval. The level of intensity thus indicates a motion level, which is a measure for the physical load of the person.

In practice, the storage unit 34 is realized by a small microchip. By including an additional storage unit 34 the estimation of the $HR_{constant}$ and thus also the estimation of the heart rate development during the transition period becomes more efficient. The

processing unit 18 analyses the previous recorded data and uses the parameters deduced from this data for the estimation of the heart rate development during the transition period.

As exemplarily shown in the block diagram of Fig. 4, the portable device 10 may further include a first input interface 36, e.g. a small key pad or touch pad that allows the user 20 to manually select a type of physical activity he wants to perform. The user 20 may, for example, select a physical activity, such as running, cycling, rowing or weightlifting, from a predefined list. If the processing unit 18 additionally receives information about the type of physical activity, this simplifies the determination of the motion frequency. This again relies on the fact, that each type of physical activity in practice generates a different kind of pattern of the detection motion signal 24.

As further shown in the block diagram of Fig. 4, the portable device may additionally comprise a second input interface 38. This second input interface 38 may also be a key pad or touch pad that the user 20 uses to manually enter his/her personal data that physiologically influence the heart rate and its development over time. Possibly important personal data may be e.g. the age, the gender, the body weight, the body height and/or the resting heart rate.

Thus, the user 20 may directly enter his personal data that can be used to improve the estimation of the heart rate 26 in the second mode of the processing unit 18, when the optical heart rate sensor 14 fails to deliver a reliable heart rate signal 22. The entered personal data may also be used to apply an additional physiological model, which model can be used to adapt the estimated heart rate development during the transition period. Exemplary physiological models are known from the above-mentioned scientific paper.

It is to be noted that this second input interface 38 is not necessarily needed, since at least a few of the personal parameters, such as the HR_{rest} and the personal fitness parameter a, may also be derived from the motion signal 24 in the way mentioned above. Further, it is to be noted that the first input interface 36 and the second input interface 38 may be realized by the same key pad (as this is schematically illustrated in Fig. 4).

According to the illustrated second embodiment, the portable device 10 furthermore comprises a display 40. The display 40 may, for example, be a small LED array that is integrated into the portable device 10 and used to visualize/display the calculated heart rate 26 to the user 20 in real time.

Fig. 5 to 7 show three exemplary measurements that have been recorded with an optical heart rate sensor during a running activity of the user 20. The top diagrams (Fig. 5a, 6a and 7a) show the heart rate signal 22, 22', 22'', measured in beats per minute (Y-axis),

over the time, measured in seconds (X-axis). The bottom diagrams (Fig. 5b, 6b and 7b) show the corresponding recorded heart rate quality signal 30, 30', 30'' and the motion rate quality signal 32, 32', 32'' over the corresponding time periods.

The measurements shown in Figs. 5a, 6a and 7a show the uncorrected heart rate signal 22, 22', 22'', meaning that these heart rate signals 22, 22', 22'' have only been measured with the optical heart rate measurement unit 14 and have not been corrected by the received motion data.

In Fig. 5, it can be seen that this heart rate measurement fails in the time period between 500 and 700 sec (time period highlighted with circles). In this time period, the heart rate quality signal 30 is very low and tends to almost zero. The motion rate quality signal 32 instead shows rather high values, which is an indicator that there is a large movement of the portable device 10. This results in an unreliable development of the heart rate signal 22 within this time period.

In this time period the measured heart rate signal 22 has a very discontinuous development including strong variations, which of course does not match the "real" heart rate behavior. This relies on the above-mentioned effect that large motion artifacts are introduced into the heart rate signal 22 if high accelerations occur.

Similar examples are shown in Figs. 6 and 7. Herein, the failure of the heart rate measurement unit 14 occurs in the time period of 400 to 700 sec (Fig. 6) or of 100 to 700 sec (Fig. 7). This is identified by the corresponding heart rate quality signals 30', 30'' that become very low in these time periods and indicate that the measured heart rate data cannot be relied upon.

Figs. 8 to 10 show the same graphs, wherein the estimated heart rate signals 23, 23', 23'' that have been calculated/estimated using the presented portable device 10 are plotted therein as well. Fig. 8 refers to the same failure instance as Fig. 5, Fig. 9 to the one of Fig. 6, and Fig. 10 to the one of Fig. 7. The graphs furthermore include a plot of the "real" heart rate signals 42 that have been measured with an ECG device in order to receive the real heart rate development as a reference.

It can be seen from Figs. 8 to 10 that the heart rate signals 23, 23', 23'' estimated with the portable device 10 are very close to the reference signals 42, 42', 42''. It has to be noted that the estimated heart rate signals 23, 23', 23'' have been estimated based on the motion signal 24 in the way explained above. In the time periods, in which the heart rate measurement unit 14 delivers reliable measurement results (e.g. in the time periods 0 to 400 and 700 to 1850 in the examples shown in Fig. 6 and 9), the heart rate signals 23, 23',

23'' are the heart rate signals which are directly measured with the heart rate measurement unit 14. In the time periods, in which the measurement of the heart rate measurement unit 14 fails (e.g. in the time period 400 to 700 sec in Figs. 6 and 9), the heart rate signal 23, 23', 23'' is estimated based on the motion signal 24 using one of the above-mentioned estimation methods. This results in a rather realistic heart rate calculation/estimation at all times of the measurement.

The presented portable device and the corresponding method allow to detect the heart rate of an athlete or a sportsman in many different situations, even in situations where large movements occur and a state of the art optical heart rate sensor would not be able to reliably detect the heart rate. As explained in the foregoing, the processing unit is adapted to switch between two modes. In the first mode, the heart rate is calculated based on the heart rate signal if the signal quality is above a predefined threshold. If on the other hand, the processing unit is not able to reliably calculate the heart rate based on the heart rate signal, the processing unit switches to a second mode in which the heart rate is estimated from motion, by using a model in which the data is compared with a set of values determined from previous measurements or introduced as input by the user. The presented method thereby makes use of one of the following features, or any combination thereof:

1. The history of the good measurements up to the point of failure,
2. an indication of the quality of the measurements made, which tells that the last measurement is a failure,
3. a profile of the user that can be either be pre-recorded or determined from the reliable measurements, and/or
4. a physiological model that makes use of parameters that are determined from previous measurements from the same user.

As it can be seen from Fig. 11, the presented method does not necessarily need to be implemented in a portable device 10. Similarly, a system 100 may be provided that comprises a portable heart rate measurement device 44 and a portable motion measurement device 46 that may be included into the same casing. The difference between the shown system 100 and the portable device 10 is that no portable processing unit 18 is integrated into the portable device. Instead, the signals measured by the portable heart rate measurement device 44 and the portable motion measurement device 46 may be transferred to an external processing device 48 which performs the above-mentioned calculations/estimations externally. By using a wireless connection between the portable devices 44, 46 and the processing device 48 this data transfer may also be realized in real time. However, it is also

possible that the data recorded by the portable devices 44, 46 are stored in a storage unit and transferred afterwards to the processing device 48 (after the measurement).

In order to establish a real time connection, the portable devices 44, 46 preferably comprise a communication interface (for simplicity reasons not shown) such as e.g. a radio transmitter, whereas the processing device also includes a similar communication interface such as e.g. a radio receiver. For the rest, it shall be understood that the system 100 has similar and/or identical preferred embodiments as the claimed portable device 10.

While the invention has been illustrated and described in detail in the drawings and foregoing description, such illustration and description are to be considered illustrative or exemplary and not restrictive; the invention is not limited to the disclosed embodiments. Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality. A single element or other unit may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

A computer program may be stored/distributed on a suitable medium, such as an optical storage medium or a solid-state medium supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems.

Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. A portable device for determining a heart rate (26) of a person (20), said portable device (10) comprising:

- a heart rate measurement unit (14) for measuring the heart rate (26) of the person (20) over time to generate a heart rate signal (22),
- a motion measurement unit (16) for measuring the motion of a body part (12) of the person (20) over time to generate a motion signal (24), and
- a processing unit (18) which is adapted to measure a signal quality (30) of the heart rate signal (22), to calculate the heart rate (26) based on the heart rate signal (22) if said signal quality (30) is above a predefined threshold, and to estimate the heart rate (26) based on the motion signal (24) if said signal quality (30) is below said threshold.

2. A portable device as claimed in claim 1, wherein the heart rate measurement unit (14) comprises an optical sensor, in particular a photoplethysmography (PPG) sensor for measuring a blood pulse wave of the person (20) over time to generate the heart rate signal (22).

3. A portable device as claimed in claim 1, further comprising a display (40) for displaying the calculated heart rate (26).

4. A portable device as claimed in claim 1, wherein the processing unit (18) is adapted to determine the signal quality (30) of the heart rate signal (22) in the frequency domain by analyzing the spectral peaks of the heart rate signal (22) at a heart rate frequency and/or its harmonics.

5. A portable device as claimed in claim 1, wherein the processing unit (18) is adapted to estimate the heart rate (23, 26) based on the motion signal (24) by estimating a heart rate constant ($HR_{constant}$) and defining an exponential development of the heart rate (26) over time, wherein the exponential development of the heart rate (26) starts at the last reliably measured heart rate and finishes at the estimated $HR_{constant}$, the $HR_{constant}$ being an estimated

heart rate of the person (20) which depends on the frequency of the motion signal (24), and the last reliably measured heart rate being the last measured heart rate with the heart rate measurement unit (14) at a point in time before under-running said threshold.

6. A portable device as claimed in claim 5, wherein the exponential development is an exponential curve indicating the heart rate over time, which exponential curve has a time constant a, a being a constant related to the person's fitness which decreases with increasing fitness.

7. A portable device as claimed in claim 5, wherein the processing unit (18) is adapted to calculate the $HR_{constant}$, with $HR_{constant} = 2{,}1 * f - a$, where f is the frequency of the motion signal (24), and a is a constant indicating the person's fitness with $a = 75 - HR_{rest}$, and HR_{rest} being the resting heart rate of the person (20).

8. A portable device as claimed in claim 1, further comprising a storage unit (34) which is adapted to store reference measures for heart rates belonging to known levels of intensity of the person's physical activity, wherein the processing unit (18) is adapted to determine a level of intensity of the person's physical activity based on the generated motion signal (24), and to determine the heart rate constant ($HR_{constant}$) by comparing the determined level of intensity with the reference measures stored in said storage unit (34) if the signal quality (30) of the heart rate signal (22) is below said threshold.

9. A portable device as claimed in claim 8, wherein the processing unit (18) is adapted to determine the level of intensity of the person's physical activity based on a frequency, on at least one peak value of the generated motion signal (24) and/or based on the average amplitude of the generated motion signal (24) over a time-interval.

10. A portable device as claimed in claim 1, further comprising a first input interface (36) for receiving information about a type of physical activity of the person (20), wherein the processing unit (18) is adapted to estimate the heart rate (26) based on the motion signal (24) and the type of physical activity if the signal quality (30) of the heart rate signal (22) is below said threshold.

11. A portable device as claimed in claim 1, further comprising a second input interface (38) for receiving the person's personal data, in particular an age, a gender, a body weight, a body height and/or a resting heart rate, wherein the processing unit (18) is adapted to estimate the heart rate (26) based on the motion signal (24) and the received personal data if the signal quality (30) of the heart rate signal (22) is below said threshold.

12. A portable device as claimed in claim 1, further comprising a frequency filter to filter out the frequency components within the heart rate signal (22) which are due to motion of the device (10), and wherein the processing unit (18) is adapted to determine the signal quality (30) of the filtered heart rate signal.

13. A method for determining a heart rate (26) of a person (20), including the steps of:

- measuring the heart rate (26) of the person (20) over time to generate a heart rate signal (22),
- measuring the motion of a body part (12) of the person (20) over time to generate a motion signal (24),
- measuring a signal quality (30) of the heart rate signal (22), and
- calculating the heart rate (26) based on the heart rate signal (22) if said signal quality (30) is above a predefined threshold, and estimating the heart rate (26) based on the motion signal (24) if said signal quality (30) is below said threshold.

14. A system for determining a heart rate (26) of a person (20), said system (100) comprising:

- a portable heart rate measurement device (44) for measuring the heart rate (26) of the person (20) over time to generate a heart rate signal (22),
- a portable motion measurement device (46) for measuring the motion of a body part (12) of the person (20) over time to generate a motion signal (24), and
- a processing device (48) which comprises a communication interface for receiving said heart rate signal (22) and said motion signal (24), and a processing means which is adapted to measure a signal quality (30) of the heart rate signal (22), to calculate the heart rate (26) based on the heart rate signal (22) if said signal quality (30) is above a predefined threshold, and to estimate the heart rate (26) based on the motion signal (24) if said signal quality (30) is below said threshold.

15. A computer program product comprising program code means for causing a computer to control a portable device as claimed in claim 1 to carry out the steps of the method as claimed in claim 14 when said computer program is carried out on the computer.

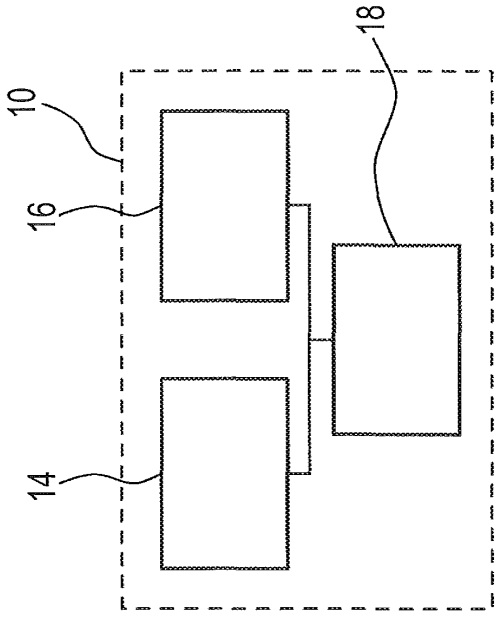

Fig. 2

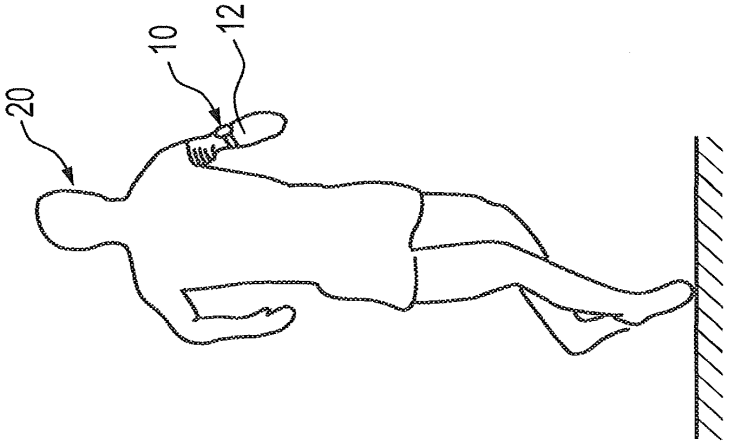

Fig. 1

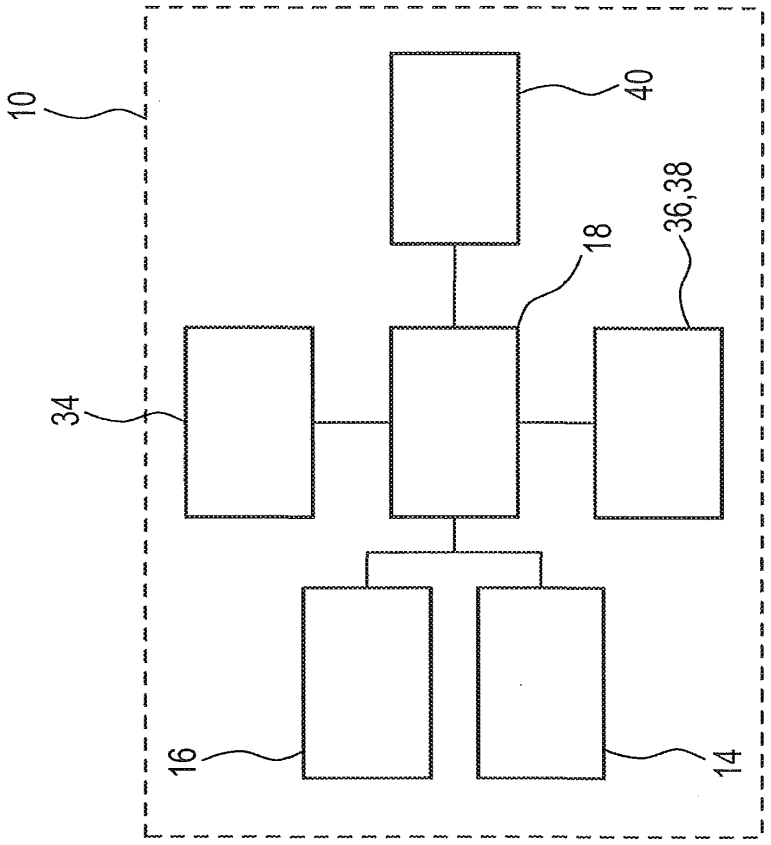

Fig. 4

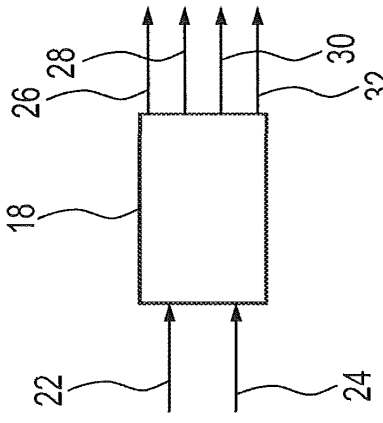

Fig. 3

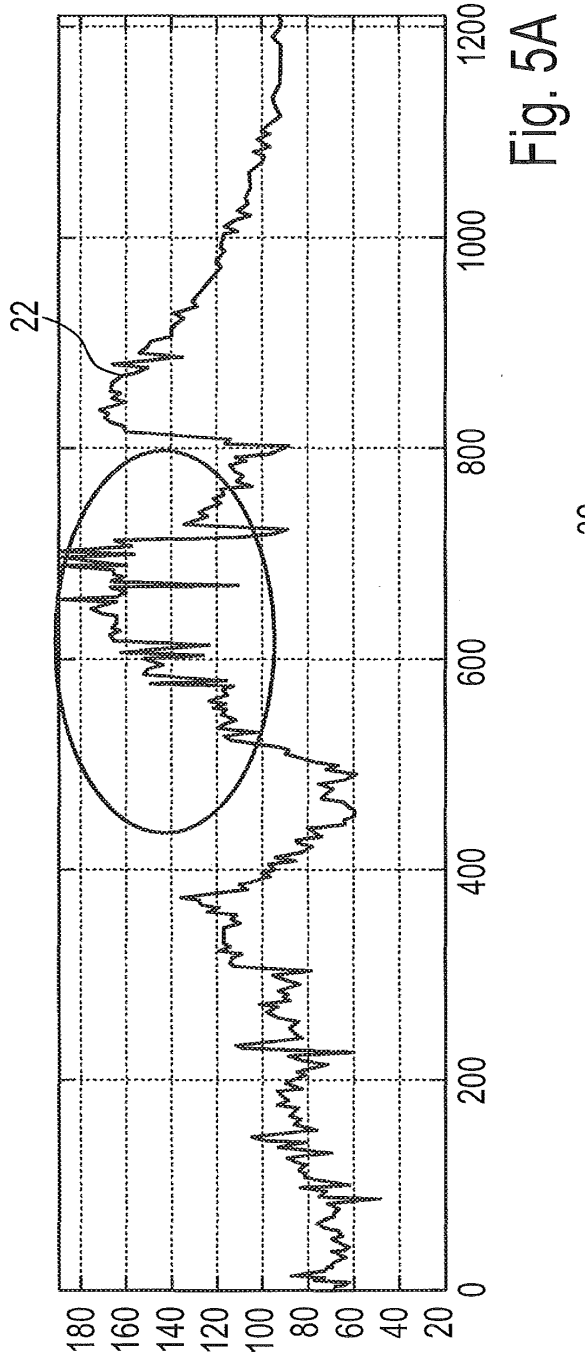

Fig. 5A

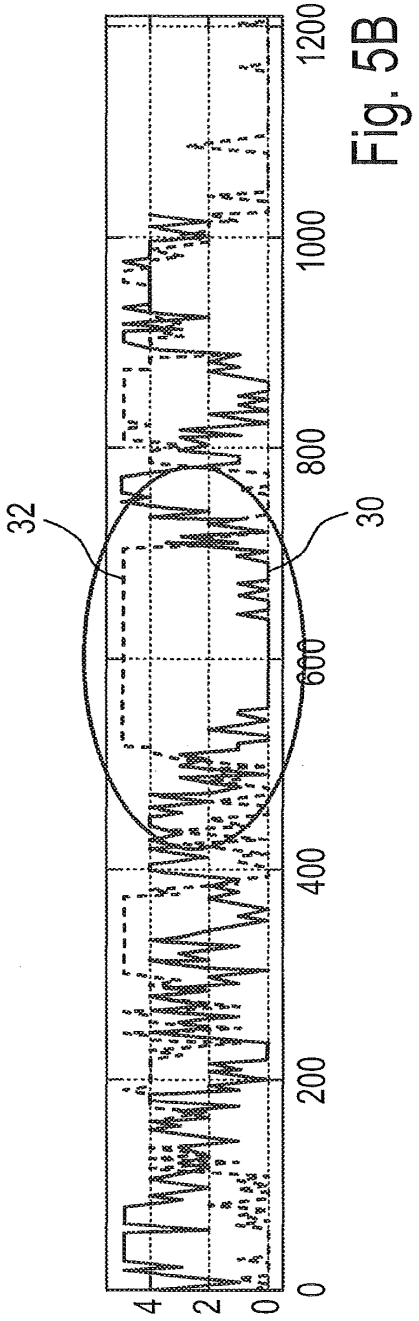

Fig. 5B

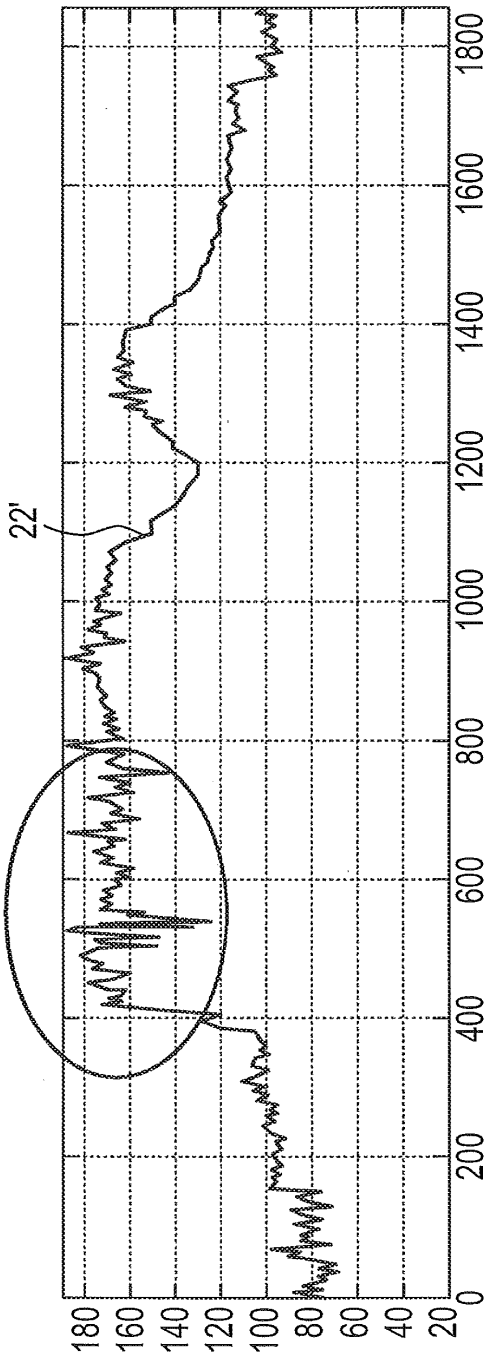

Fig. 6A

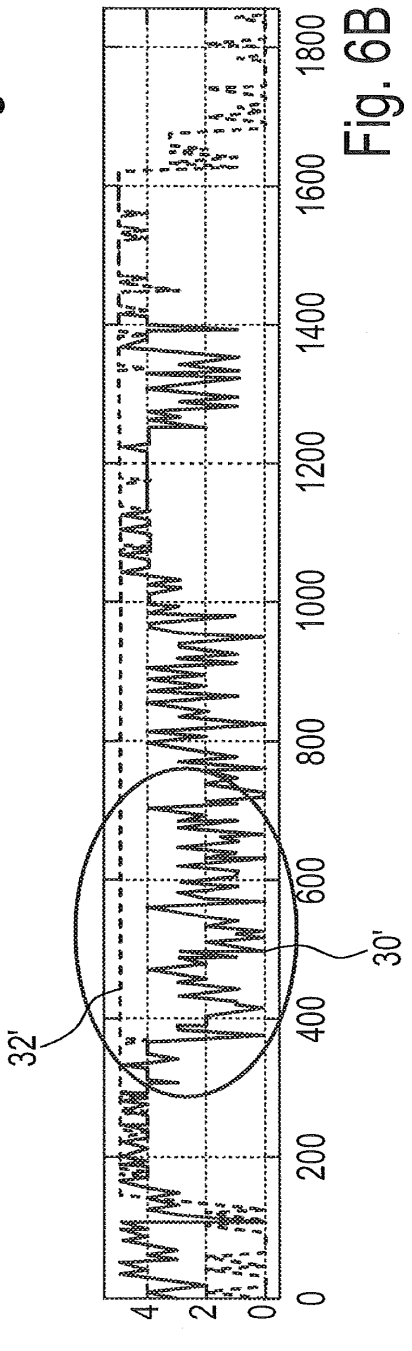

Fig. 6B

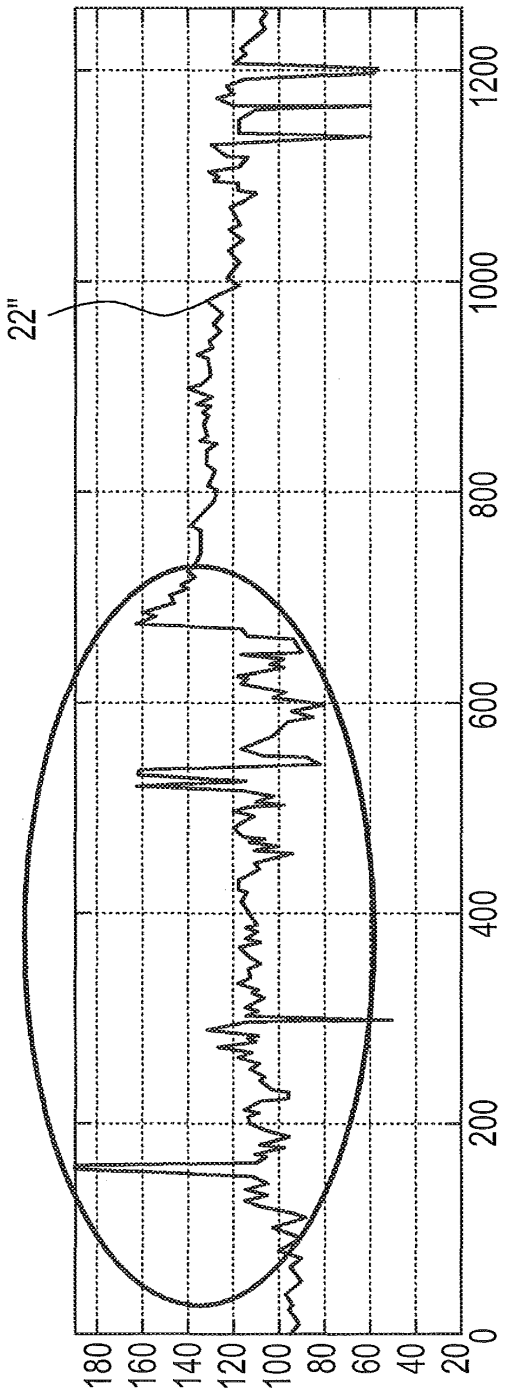

Fig. 7A

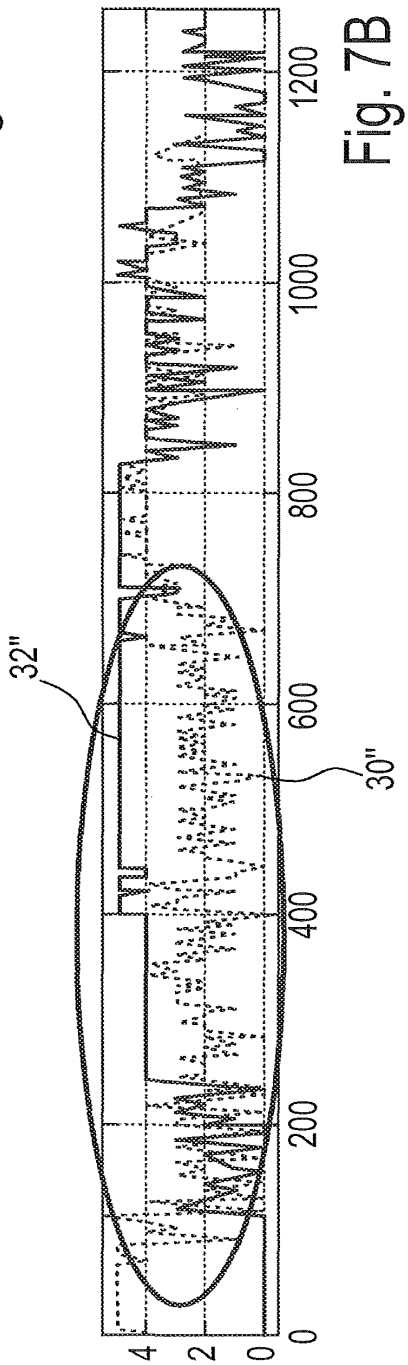

Fig. 7B

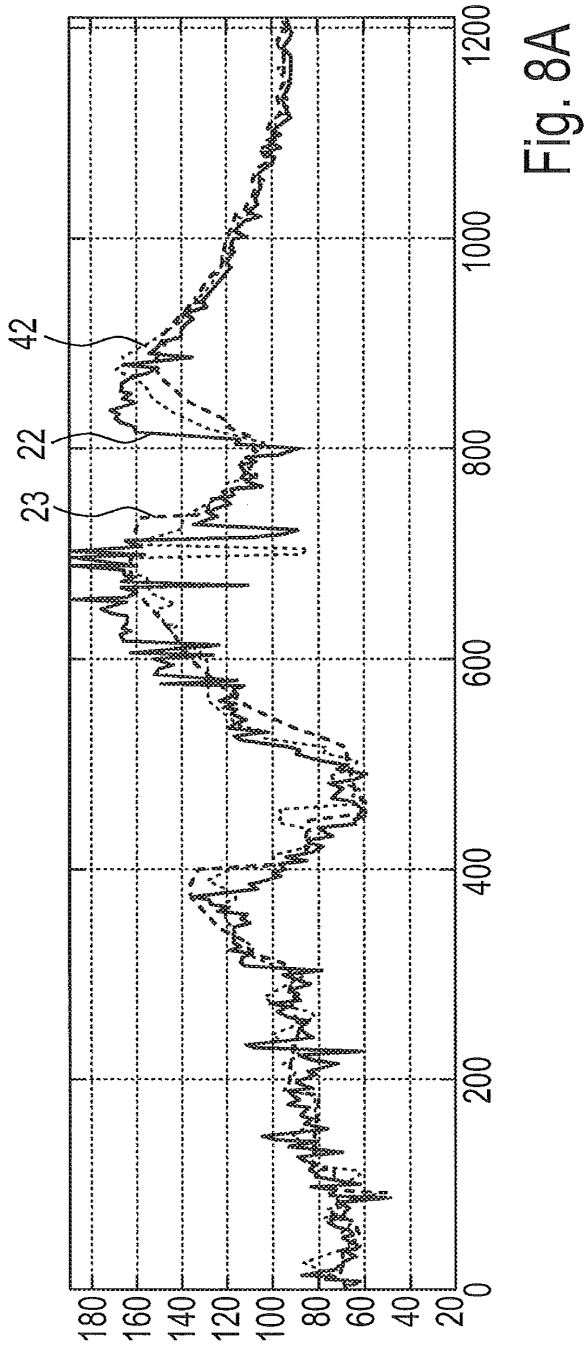

Fig. 8A

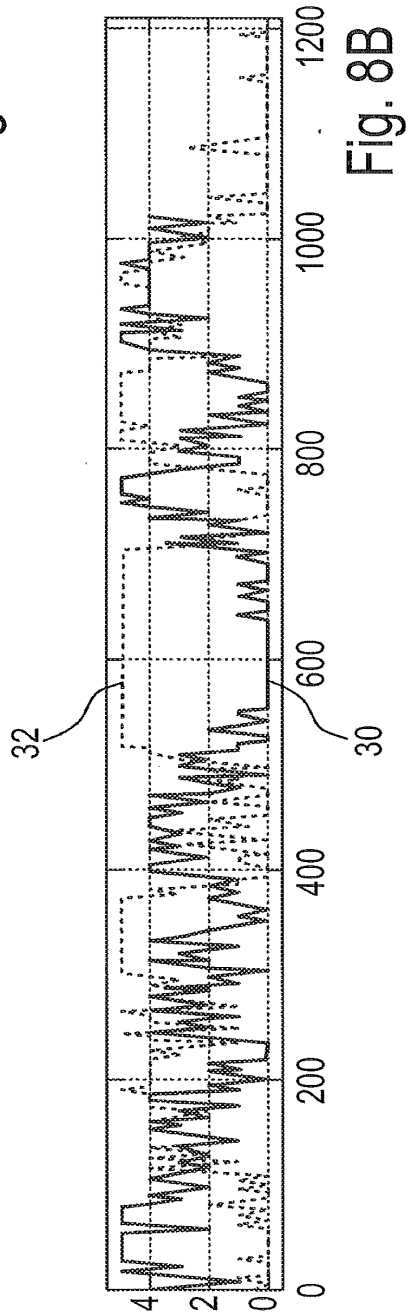

Fig. 8B

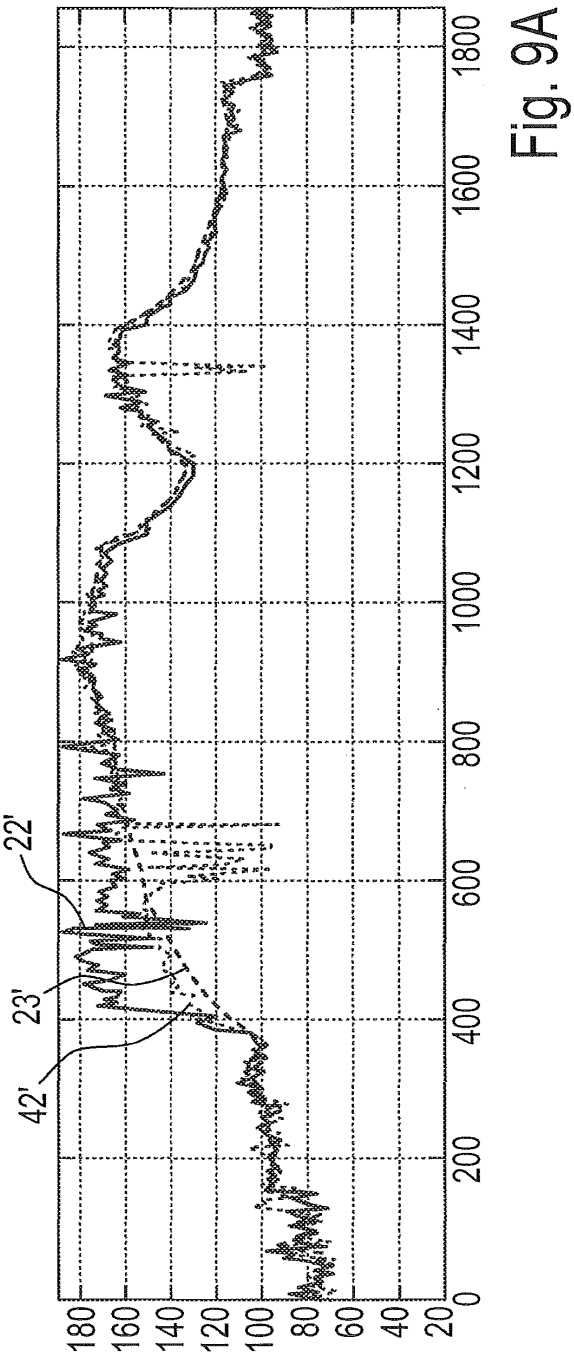

Fig. 9A

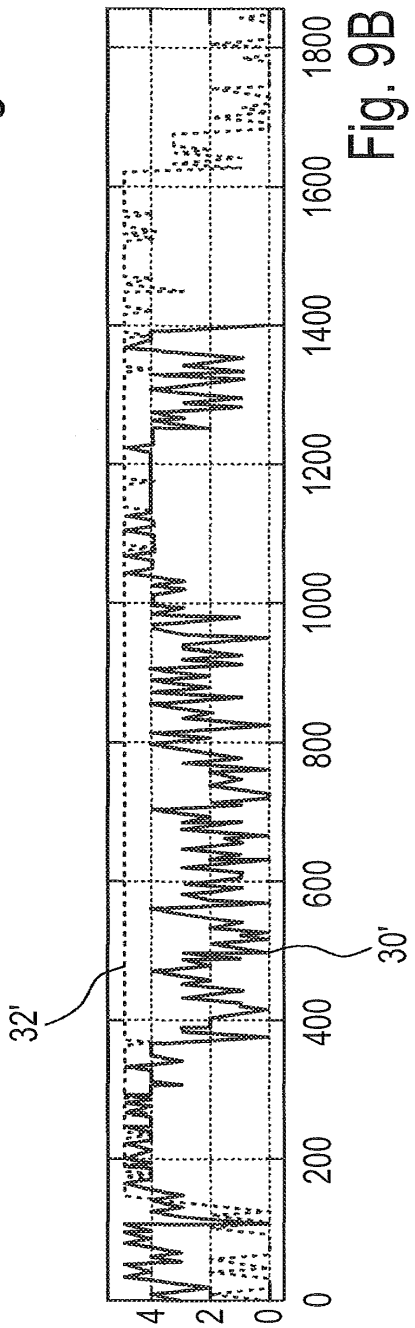

Fig. 9B

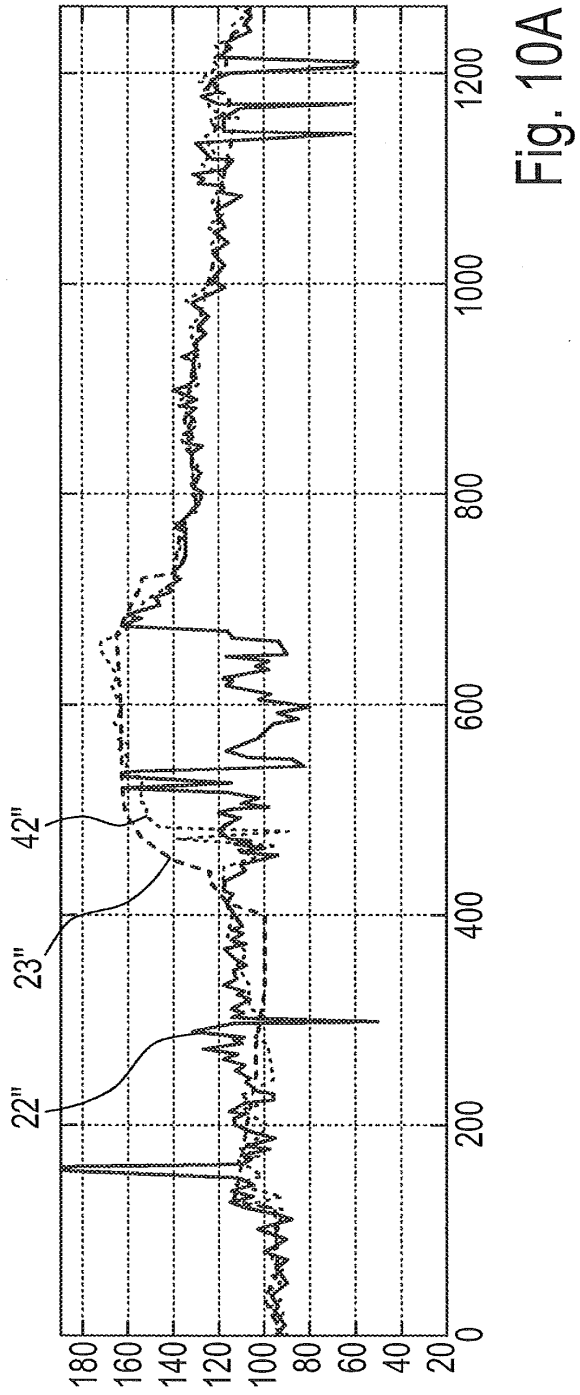

Fig. 10A

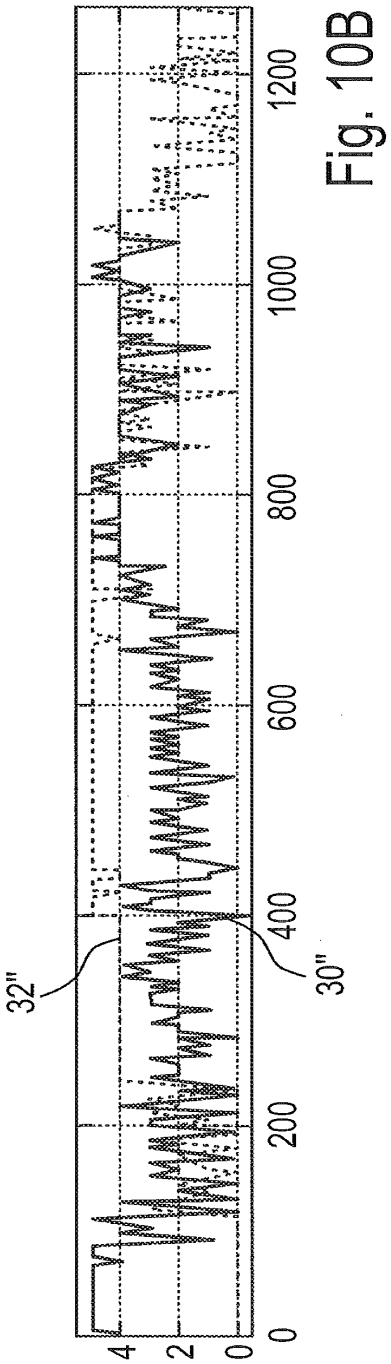

Fig. 10B

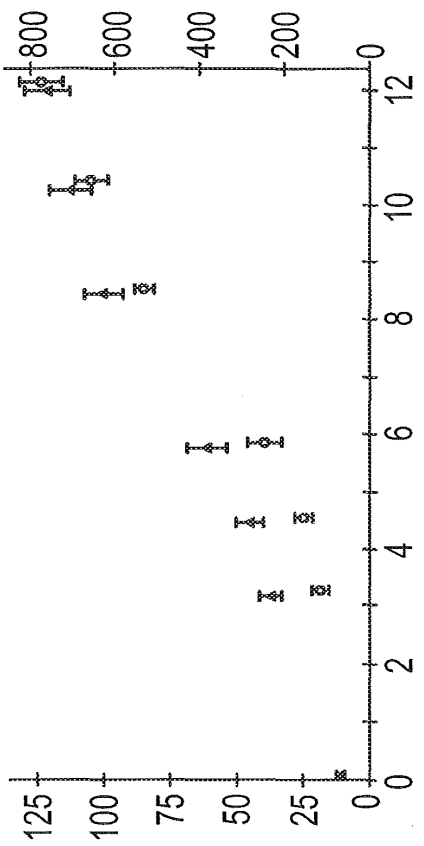

Fig. 12

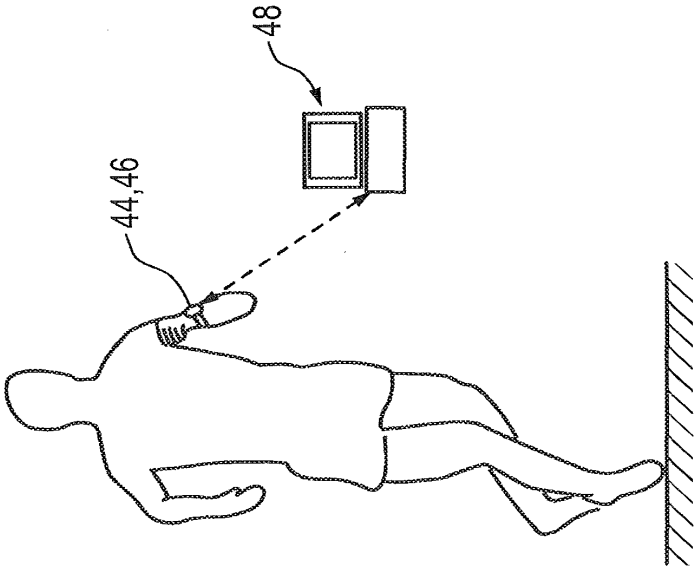

Fig. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/054553

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/024 A61B5/11
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B A63B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 733 340 A1 (SEIKO INSTR INC [JP]; SEIKO EPSON CORP [JP]) 25 September 1996 (1996-09-25)	1,3, 12-14
Y	column 4, line 55 - column 5, line 38	2,4
A	column 13, line 19 - column 15, line 50; figures 13, 14, 15A, 15B	5
Y	US 2002/035315 A1 (ALI AMMAR AL [US] ET AL) 21 March 2002 (2002-03-21) paragraphs [0003], [0004], [0041], [0089] - [0094]	2,4
A	US 2006/084879 A1 (NAZARIAN RICHARD A [US] ET AL) 20 April 2006 (2006-04-20) paragraphs [0057] - [0066]	1,13,14

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 October 2012	07/11/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Küster, Gunilla

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/054553

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 1 908 401 A1 (ETA SA MFT HORLOGERE SUISSE [CH]) 9 April 2008 (2008-04-09) paragraphs [0012], [0018] - [0025]	1,13,14
A	US 2011/066381 A1 (GARUDADRI HARINATH [US] ET AL) 17 March 2011 (2011-03-17) paragraphs [0017], [0044] - [0048], [0058]	1,13,14
A	US 2008/214963 A1 (GUILLEMAUD REGIS [FR] ET AL) 4 September 2008 (2008-09-04) the whole document	1,13,14
A	RENEVEY P ET AL: "Wrist-located pulse detection using IR signals, activity and nonlinear artifact cancellation", 2001 PROCEEDINGS OF THE 23RD ANNUAL EMBS INTERNATIONAL CONFERENCE, vol. 3, 25 October 2001 (2001-10-25), pages 3030-3033, XP010592313, ISBN: 978-0-7803-7211-5 the whole document	1,13,14

Form PCT/ISA/210 (continuation of second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2012/054553

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		DE 69634147 T2	16-02-2006
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(54) Exercise device, sensor and method of determining body parameters during exercise

(57) A noninvasive light sensor for detecting heart beat signals has a circular support member engageable circumferentially with a body part of a person. There are a plurality of light emitters and light detectors located in pairs symmetrically about a circumference of the circular support member for respectively emitting light signals into different areas of tissue surrounding the body part, and receiving reflected light signals from the different areas of tissue surrounding the body part.

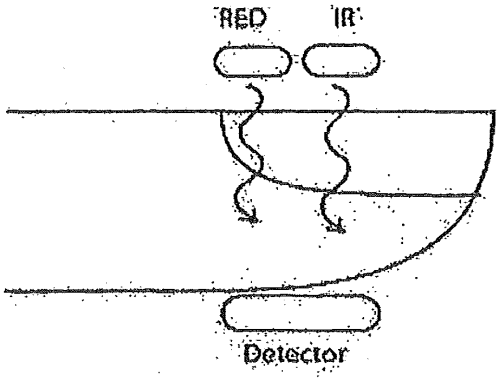

Figure 1 (Prior Art)

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Description

Field of the Invention

[0001] The current invention relates to an exercise device for monitoring body parameters of a wearer during exercise. The invention also relates to sensor for determining sensor signals from which body parameters can be derived and to a method of determining body parameters during exercise.

Background to the Invention

[0002] To achieve fitness goals it is necessary to exercise in the right intensity. Heart rate is one of the most accurate measurements of the intensity or exertion level of an exercise workout. The fitness of the heart is the key to aerobic endurance. Aerobic endurance is extremely important for both general fitness training and professional athletes. Heart monitors are one of the most effective aids for tracking and developing the progress on the path to increased aerobic endurance. For example, to loss weight and bum fat, it is desirable to exercise at 60-70% of one's maximum heart rate. To improve cardiovascular fitness, it is more suitable to exercise at 70-80% of one's maximum heart rate. Exercise at the wrong intensity will just waste the effort or may even harm the body.

[0003] Heart rate can easily be checked by checking the pulses at the wrist manually for, say, 15 seconds during exercise and calculate beats per minute. However, stopping during exercise to count pulse is not only inconvenient, but also disrupts both the workout and the heart rate. This method also introduces pressure to the carotid artery which slows down the pulse. Electronic heart monitors are an effective way to track and record heart rate over the course of an entire workout. They not only provide a complete record of the heart rate for the duration of your workout, but they are also more accurate than manual methods, and can provide other information such as body temperature, Sp02 (Oxyhemoglobin saturation by pulse oximetry) are also important information to determine condition of the body.

[0004] For professional athletes, cardiovascular fitness is the most significant factor in speed. Measuring the work-rate of the heart is one of the most accurate methods of determining how much benefit an athlete derives from a workout. A heart rate monitor can also help to avoid stressing the body too much. They are a useful tool for maximize the efficiency of the training while minimizing the opportunity for injury. Heart rate monitors also enable professional athletes to exercise below a certain ceiling, i.e. avoid depleting the body's glycogen stores and ensuring that the body has the energy to perform intense workouts with vigor. For general fitness training, a heart rate monitor can function as a coach guiding the user when he or she can handle more and work harder.

[0005] Most popular heart rate monitors use ECG type chest belt with a wireless link to sports watch. The heartbeat is detected by sensing the ECG signal from the chest belt and a pulse is sent to the sports watch via wireless connection. This type of heart rate monitor is accurate and reliable, but has the disadvantage that it is not comfortable for the user to wear a plastic belt on the chest during exercise. The belt will also become very dirty after use. Another method of detecting heartbeat is to use IR LED and IR sensor through the ear lobe or finger tip. This type of detector has the intrinsic problem of motion artifact and they are simply not reliable during exercise.

[0006] There are many devices that can measure body parameters of a person. For example, by using an infrared ear thermometer, clinical thermometer, the user could get his body temperature and by using pulse oximeter the user could get his heartbeat and the amount of oxygen attached to the hemoglobin. However, none of these devices is suitable for continuous monitoring of the body parameter when the user is doing exercise. The thermometer, for example, is not suitable for use in motion. For finger pulse oximeter, study suggested the motion will result in blood volume changes that invalidate its measurement [ref - "Motion Artifact in Pulse Oximetry", M.R. Neuman and N. Wang, Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Vol. 12 No. 5, 1990].

[0007] Figure 1 is a schematic illustration is a typical finger type pulse oximeter implementation. Measuring heartbeat rate and Sp02 (blood oxygenation) is based on the absorption of red and infrared light. The technology is very sensitive to motion and hence is generally not suitable for use in personal exercise monitors. A few mechanical designs attempt to improve motion tolerance and enable the measurement to be used later in signal processing such that the heart rate in addition to Sp02 can be derived when the wearer is in motion. The device comprises two light sources, typically using LEDs of known wavelength. The wavelengths of the two light sources are 880 - 920nm (Infrared or IR) and 660nm (Red) respectively. To obtain heart rate (HR) only the IR light source is needed. To calculate blood oxygen levels (pulse oximetry) both the Red and the IR LED's would need to be used. In either case a photo detector is used to sense the light that has been transmitted or reflected into the skin or application sight. This transmission of light into an area of the body that is carrying blood and reflected back to the photo detector will be effected by the pulsiltile flow caused by each heartbeat. This slight change in light intensity is detected and extracted to create a waveform commonly known as a plethysmograph. This waveform or the actual detection of the pulsiltile flow can be converted into heart rate in the absent of motion. To calculate pulse oximetry the IR and the red light emissions are separately analyzed and then used in an empirical calculation to generate a predetermined blood oxygen level. The calibration and empirical calculation

can be found in many literatures.

[0008] Figure 2 shows an example of noise induced by motion in an IR LED and IR heartbeat/SpO2 sensor. This noise signal may be of similar or even larger amplitude than the heartbeat signal and they are, in normal situation, in the same frequency band of the heartbeat signal (1-3 Hz). There is no easy method to extract the heartbeat signal from the mixture of the motion signal and heartbeat signal.

[0009] In addition to heart rate people are also interested in measuring the the distance run in an exercise session. There are many pedometer devices in the market that can count steps when a person walks or runs. These pedometers are fairly accurate and can record number of steps for a long period of time. Most of these devices require user to wear the device at particular orientation and position of the body trunk for the devices to work. These devices will usually fail if users are holding the device in hand when running or jogging.

Summary of the Invention

[0010] Accordingly, is an object of the present invention to provide an exercise device for determining the body parameters of a wearer during exercise. This particular object of the present invention to provide a sensor and method of determining heartbeat from a sensor signal that overcome or at least ameliorates problems with known devices. It is a second object of the current invention to provide an exercise device the can detect steps and calculate distance run by a user.

[0011] According to a first aspect of the invention there is provided a noninvasive light sensor for detecting heart beat signals, comprising:

a circular support member engageable circumferentially with a body part of a person,
a plurality of light emitters located about a circumference of the circular support member for emitting light signals into different areas of tissue surrounding the body part, and
a plurality of light detectors located about a circumference of the circular support member for receiving reflected light signals from the different areas of tissue surrounding the body part.

[0012] Preferably, the light emitters and light detectors are located in pairs consisting of one of the emitters and one of the detectors.

[0013] Preferably, the light emitters comprises both red and infra-red light emitters.

[0014] Preferably, the plurality of light emitters consist of three light emitters located 120 degrees apart about the circumference of the support member.

[0015] Preferably, the plurality of light detectors consist of three light detectors located 120 degrees apart about the circumference of the support member.

[0016] Preferably, the light emitters and light detectors are located in pairs consisting of one of the emitters and one of the detectors.

[0017] Preferably, the support member is one of a ear bud insertable within an ear canal or a band locatable about a wrist or arm.

[0018] Preferably, the body part is an ear canal, the circular support member being an ear bud insertable with the an ear canal along an ear canal axis, wherein the plurality of light emitters are located about the periphery of the ear piece for emitting light signals perpendicular to the ear canal axis into the different areas of tissue surrounding the ear canal, and the plurality of light detectors are located about the periphery of the ear piece for receiving reflected light signals from the different areas of tissue surrounding the ear canal. '

[0019] Preferably, the ear piece is resiliently deformable for expansion within the ear canal, such that the ear piece is firmly locatable within the ear canal.

[0020] Preferably, the ear price comprises an inner layer and an outer layer having a plurality of openings, the light emitters and light detectors located with the inner layer beneath the outer layer openings.

[0021] Preferably, the inner lay comprises foam and the outer layer comprises rubber.

[0022] Preferably, the ear piece has an outer surface for mating with the ear canal and a plurality of openings in the outer surface, the light emitters and light detectors located within the openings.

[0023] Preferably, the light emitters and light detectors are located below the outer surface of the ear piece.

[0024] Preferably, the openings have sides surrounding the light emitters and light detectors, the sides defining a narrow gap above the light emitters and light detectors.

[0025] Preferably, the sides of the openings are light absorbent.

[0026] Preferably, the noninvasive light sensor of further includes an audio speaker and/or a temperature sensor.

[0027] Preferably, the body part is a wrist or arm, the support member comprising a band locatable about a wrist or arm, the emitters and detectors located around an inner circumference of the band for respectively emitting light signals into the different areas of arm tissue and receiving reflected light from the different areas of arm tissue.

[0028] According to a second aspect of the invention there is provided a exercise device comprising:

a ear piece insertable with the an ear canal along an ear canal axis, a plurality of light emitters located about the periphery of the ear piece for emitting light signals perpendicular to the ear canal axis into different areas of tissue surrounding the ear canal, a plurality of light detectors located about the periphery of the ear piece for receiving reflected light signals from the different areas of tissue surrounding the ear canal, and a audio speaker,
an audio player for sending audio signals to the audio speaker,
a vital sign monitor that can determine at least one of heart rate, blood oxygen level or body temperature from signals of the emitters and detectors.

[0029] According to a third aspect of the invention there is provided a exercise system comprising:

an ear piece insertable within an ear canal along a canal axis, the ear piece having a plurality of light sensors and detectors, and a audio speaker,
a computer readable storage medium have space allocated for storage of audio files,
a vital sign monitor programmed to generating a vital sign signal from signals of the emitters and detectors, and
an audio player programmed to playback audio files thought the audio speaker in response to the vital sign signal and to vary attributes of the playback audio files in response to the vital sign signal.

[0030] Preferably, the attributes of the playback audio files to be varied are beat, tempo, tone and pitch.

[0031] Preferably, the audio player is programmed to vary the attributes by changing the playback audio files.

[0032] Preferably, the vital sign monitor is programmed to generating a heart rate, blood oxygen or temperature signal.

[0033] According to a fourth aspect of the invention there is provided a method of determining heart rate of a person during exercise comprising:

obtaining a plurality of sensor signals from multiple locations about a body part of a person, the sensor signals comprising a heart beat signals and a movement signals,
comparing the signals to separate the heart beat signals and a movement signals, and
determining heart rate from the heart beat signals.

[0034] Preferably, obtaining a plurality of sensor signals from locations comprises providing a plurality of heart beat sensors for positioning at multiple locations about the body part.

[0035] Preferably, comparing the signals to separate the heart beat signals and a movement signals comprises comparing the sensor signals to find in phase and out of phase components of the sensor signals.

[0036] Preferably, comparing the signals to separate the heart beat signals and a movement signals comprises finding a covariance between the sensor signals.

[0037] Preferably, determining heart rate from the heart beat signals comprises using match filters.

[0038] According to a fifth aspect of the invention there is provided a method in an exercise device of determining the steps taken by a person during exercise, comprising:

obtaining a plurality of sensor signals from symmetrical locations about a body part of a person, the sensor signals comprising a heart beat signals and a movement signals,
finding a dominant movement signal, and
determining zero crossing points of the dominant movement signal.

[0039] Preferably, finding a dominant movement signal comprises finding a movement signal having an amplitude greater than a threshold.

[0040] Preferably, finding a dominant movement signal comprises finding a sum of two sensor signals, finding a product of two times a third sensor signal, and subtracting the product from the sum.

[0041] Preferably, the third sensor signal has an amplitude lower than amplitudes of the two summed sensor signals.

[0042] Preferably, determining zero crossing points of the dominant movement signal comprises determining a number of the zero crossing points.

[0043] Preferably, method further comprises finding a product of a step-distance and the number of the zero crossing points and thereby finding a distance traveled by a person exercising.

[0044] Further aspects of the invention will become apparent from the following description.

Brief Description of the Drawings

[0045] An exemplary form of the present invention will now be described by way of example only and with reference to the accompanying drawings, in which:

Figure 1 is a schematic illustration of prior art operation of a heartbeat sensor/pulse oximeter,

Figure 2 is a graphical illustration of the heartbeat signal with motion noise for a prior art earphone sensor,

Figure 3 is a schematic illustration of a first embodiment of a personal exercise device according to the invention having an earphone type sensor,

Figure 4 is a schematic illustration of the earphone sensor arrangement for device of Figure 3,

Figure 5 is a perspective illustration of an ear bud of the earphone sensor,

Figure 6 is a schematic illustration of a flexible printed circuit for locating and connection of sensors within the ear bud,

Figure 7 is a perspective illustration of the ear bud without a rubber over-molding,

Figure 8 is a section illustration of the ear bud,

Figure 9 is a perspective illustration of an alternative ear bud type earphone sensor and behind-the-ear parts of the alternative ear bud,

Figure 10 is a perspective illustration of a bud,

Figure 11 is a schematic illustration of a second embodiment of a personal exercise device according to the invention having a arm band type sensor,

Figure 12 is a second schematic illustration of the personal exercise device having a arm band type sensor,

Figure 13 is a schematic illustration of the sensor control and processing means of the exercise device,

Figure 14 illustrates decomposition of the noise vector into horizontal and vertical components, and

Figure 15 is a schematic process block diagram of detector sensor signal processing used in the exercise device,

Figure 16 is a graphical illustration of the signal detected during exercise,

Figure 17 is a block diagram of a method for detecting steps taken by a user during walking or running,

Figure 18 is a graphical illustration of the relationship between distance and walking speed,

Figure 19 is a schematic block diagram of body parameter base playback control in the exercise device, and

Figure 20 is a flow chart of the implementation of the body parameter based playback control.

Description of the Exemplary Embodiments

[0046] Aspects of the invention will now be illustrated as practiced in a first embodiment of a personal exercise device comprising an earphone sensor for listening to audio files and also for detecting body parameters; such as heartbeat, SpO2 and temperature; during exercise, a signal processing means for resolving sensor information into heartbeat and other body parameters and a workout assistance means for providing feedback of body parameters, exercise instructions and entertainment functions such as, but not limited to, music, video, game, e-book, photo, etc. However, this is not intended to limit the scope of functionality or use of the invention. In a most basic embodiment of the invention the exercise device comprises simply an earpiece sensor and signal processing means for detecting heartbeat for feedback to the user or transmission to another device such as an exercise machine or exercise monitoring equipment. The

earphones of the invention include several mechanical design characteristics that ameliorate movement inaccuracies inherent in ear sensors known hitherto. It is not essential to the invention that all such preferred mechanical design characteristics be included in all embodiments of the invention.

[0047] Figure 3 shows the block diagram of a personal exercise device. A pair of earphones 1 that can be worn by the user is connected to a portable base unit 2 by a cable 3 having conductor means 4, 5 for carrying both audio signals and body parameter sensor signals. The portable base unit 2 has a microprocessor 8, audio module 6 for providing audio signals to the earphones, a sensor module 7 for communicating with the earphone sensors and a user interface/ display module 9 for interaction with the user. In one exercise mode the exercise device determines heartbeat of the user and then controls the playback of audio content in accordance with changes in the heartbeat. The heartbeat is also recorded for future reference and for comparing against targeted training level, etc. The earphones 1 may also include an IR thermometer or small thermistor embedded in the earphones 50 for determining body temperature. The bases unit and or earphones 50 may also include an accelerometer/G-sensor for detecting steps from running or walking motion. The earphones may also include a microphone for picking up ambient sound signal and the user could enable or disable or adjusting the ratio of the mixing of ambient sound with content playing back at will. This is necessary because of the mechanical structure for the ear buds blocks a significant part of ambient sound from reaching the user.

[0048] The earphone mechanical design is illustrated in Figures 4 through 10. Figure 4 schematically illustrates the sensor arrangement of the earphones. Signal emitter 21, 22, 23 and detector 24, 24, 26 devices are located around the circumferential periphery 27 of the earphone. The emitter and detector devices may be either Red or Infared (IR) or both for detecting heartbeat and optionally SpO2. The ear piece is of a type commonly known as an ear bud 50 which has a substantially cylindrical shape for insertion within the outer ear canal of the wearer. In the preferred embodiment the emitters and detectors are grouped in pairs 21-24, 22-25, 23-26 located 120 degrees apart about the circumferential periphery 27 of the ear bud 50. The dashed lines 30, 31, 32 show the path of the IR signals through the soft tissue surrounding the internal wall of the ear canal. A first signal 31 from emitter 21 is detected by detector 25, a second signal 32 from emitter 22 is detected by detector 26 and a third signal 33 from emitter 23 is detected by detector 24. The main signal noise is due to radial motion of the ear bud 50 in the x, y plane within the ear cannel because these movement changes the distance between the sensor and the ear canal wall, which affects the transmitted and receive signal. By using the physical construction where the IR sensors are installed in several circular symmetric locations the effect due to motion in the x, y plane can be approximated as a linear effect on the amplitude of the received signal.

[0049] Some of the signal emitted from the emitters 21, 22, 23 will be reflected from the skin surface of the ear canal. The amount of the IR signals 31, 32, 33 that is reflected from the skin also varies substantially with the aforementioned x, y plane movement of the ear bud 50 within the ear canal. The reflected light is detected by the detectors and must be allowed for in later processing to determine heartbeat and other body parameters from the detected signals. The amount of referred light that is detected by the detectors can be ameliorated by locating the emitters and detectors within recess channels 35, 36, 37 below the outer peripheral surface 28 of the ear bud 50. The recess channels 35, 36, 37 can comprise air or optical glass mediums and form a narrow angle wave guide for IR signals emitted from the emitters or entering the detectors. These wave guide cannels 35, 36, 37 produces a narrow angle beam to direct the light in such a way to allow the maximum amount signal by increasing the signal path of the light up and into deeper tissue before the light reflects and is captured by the detector. They also limiting large fluctuation in DC single picked up by detectors.

[0050] The outer part 38 of the ear bud 50 consists of a soft over-molding made of resiliently deformable memory foam or silicone rubber that dampens the effects of motion. The foam is compressed when the ear bud 50 is inserted into the ear canal and expands to hold the bud 50 firmly in the ear canal to ameliorate relative motion between the emitters and detectors and the ear canal wall during exercise movement. One possible optional feature is to make outer piece 38 removable and interchangeable for varying the size and shape to fit a wide variety of users having different size ear canals. The properties (elasticity, softness as known as durometer, memory or rebound rate) of this soft over-molding 38 are chosen to maximizing the damping effects.

[0051] The depth placement of the emitters and detectors inside the ear is also important, but not essential, to reducing the effects of motion introduced within the ear during exercise. The emitters and detector are placed at the end of the inner part of the ear bud 50 which is further into the ear canal to help reduce the effects of motion. This placement helps reduce the vibration as the inner ear part is more firmly attached to the bone and muscle (non-soft tissue) which does not move as much during exercise.

[0052] A first arrangement of an ear bud 50 is illustrated in Figures 5 through 8. The interchangeable resilient outer part 38 is sized to fit within the ear canal of a person. Figure 7 illustrates the core parts of the ear bud 50 with the resilient outer part 38 removed. The structure consists of a speaker 44, a hollow inner core 41 for sound conduction from the speaker in to the ear, an resilient inner foam structure 42 for softness and flexibility , a flexible printed circuit (FPC) 43 or thin wirings for connection to emitter and detectors and a rubber over-molding 38 for increase comfort and protection of sensors. The resilient inner foam 42 may be compressed during insertion of the bud 50 into the ear to provide further support in the ear canal.

[0053] The FPC 43 comprises a hub 46 having three 120 degree radially extending arms 47. The emitter and detector

pairs 21-24, 22-25, 23-26 are located at the distal ends of the FPC 43 and are encapsulated with epoxy. The encapsulation provides a round-top to avoid injury to the user when wearing the device and at the same time prevents the emitters and receivers from damage. An alternative approach is to use sensors with suitable packaging. The FPC arms 47 are made of a flexible material so that sensors follow the foam 42 when squeezed into the ear canal. Flexible wiring tracks are located along the radial arms 47 connecting the emitters and detectors to solder bonding pads 48 on the hub 46. In one embodiment the FPC and arms is formed as a flex circuit. The hub 46 is located centrally within the back of the ear bud 50 and the radial arms brought forward within slots 45 on the surface of foam 42. The depth of the slots 45 is designed to allow the sensors to be slightly above the foam surface. The foam 42 is then covered with the rubber over-molding 38 for increase comfort and protection of sensors.

[0054] Figures 9 and 10 illustrate an alternative arrangement of an ear bud 50 in a behind-the-ear design. The cord 3 to each bud 50, hangs around the back of the ear to also help in securing an in ear portion 51 into the ear canal and thus reducing motion introduced into the signal by exercise movement. Another feature of this design is to have the cable 3 enter at the back or bottom of the behind the ear portion. This cable placement design will reduce the motion effects that can be produced by the pulling forces of the cable during movement. Since the cable 3 can exert a force on the ear piece the reduction of its size and weight is achieved by locating some of the electronics or circuitry into a behind an ear portion 52 of the earphone. This feature reduces the number of wires and thus thickness and weight of the cable 3. There are many wires needed to drive and capture the signal from the emitters and detector as well as the wires for the audio speakers and the temperature sensor. The circuit design has a communication method between the main unit 2 and the behind the ear portion 52 circuitry.

[0055] Figures 11 and 12 illustrate a second embodiment of an exercise device according to the invention employing an arm-band type sensor. In the first embodiment the sensor was a circular ear bud for location within an ear canal, with the emitters and detectors located in pairs 120 degrees apart around the outer circumference of the bud for obtaining signals from the tissue surrounding the ear canal. In the arm-band embodiment an annular band 60 is provided which locates about the wrist 61 or upper arm 62 of the user. Emitters and detectors are provided in three pairs 64, 65, 66 at locations 120 degrees apart around the inner circumference of the band 60. The emitters and detectors are of the same type as in the ear bud, however the emitters and detectors are located on the inner circumference of the band 60 so as to be pressed up against the skin of the wrist 61 or arm 62 when the band 60 is worn. The sensor signal path is through the tissue of the wrist 61 or arm 62. The band 60 is made of a resilient material so as to fit snugly about the wrist 61 or arm 62 of the wearer and maintain the emitter and detector pairs 64, 65, 66 in position with the arm tissue. The band 60 may be a stand alone band or, as illustrated in Figures 11 and 12, may be a support strap for wearing the portable base unit 2 on the wrist 61 or upper arm 62 of the users. The arm-band embodiment may be preferable to those who run or cycle in busy traffic areas and prefer not to impair their hearing with earphones for safety reasons. The embodiment shown in Figure 11 may be, for example, a wrist watch wherein the base unit only provides visual feedback. However, in some embodiments the base unit 2 may also have an ear phone output jack for connection of a standard pair of earphones for listening to music and audio feedback from the portable exercise device if so desired.

[0056] The head phones 1 and arm bands 60 of embodiments of the invention use multiple pairs of emitters and detectors at symmetrical locations to aid the removal or minimization of the additive noise introduced in to the detected sensor signals by exercise motion of the wearer. The microprocessor 8 of the main unit 2 receives the detected sensor signals and analyses them to detect the wearer's heartbeat and other body parameters, such as SpO2. Figure 13 is a schematic block diagram of the sensor control and processing means. A LED driver control is used to send driving signals to the LED emitters 21, 22, 23. The detected signals from detectors 24, 25, 26 are amplified by op-amps 62 with DC bias control 63. The amplified analog signals go through a multiplexer 64 and an analog-to-digital (A/D) converter 65 for input to the Microprocessor 8. The signals are analyzed in Microprocessor 8 to detect the wearer's heartbeat and other body parameters.

[0057] The detected signals 31, 32, 33 are modeled as follows:

$$(1) \quad m_1(t) = L_1 I_{01}(t)(1 + \gamma_1 hb(t))(1 + N_{s1}(t) + N_{f1}(t) + z_1(t))$$

$$(2) \quad m_2(t) = L_2 I_{02}(t)(1 + \gamma_2 hb(t))(1 + N_{s2}(t) + N_{f2}(t) + z_2(t)),$$

and

$$(3)\quad m_3(t) = L_3 I_{03}(t)(1+\gamma_3 hb(t))(1+N_{s3}(t)+N_{f3}(t)+z_3(t))$$

Where:

$m(t)$, $m_2(t)$, $m_3(t)$ are the signal received at the 3 detectors respectively
$I_{01}(t)$, $I_{02}(t)I_{03}(t)$ are the transmitted signal to the IR LED emitters respectively
L_1, L_2, L_3 are constant gain of each IR sensors
$hb(t)$ is the heartbeat signal
$\gamma_1,\gamma_2,\gamma_3$ are coupling coefficients of the heartbeat signal $hb(t)$
$N_{s1}(t)$, $N_{s2}(t)$, $N_{s3}(t)$ are slow varying noise in the detected signals
$N_{f1}(t)$, $N_{f2}(t)$, $N_{f3}(t)$ are typical additive thermal noise in the detected signals, and
$z_1(t),z_2(t),z_3(t)$ are noise signals due to motion.

[0058] This model is based on the assumption that the motion signals $z_1(t)$, $z_2(t)$, $z_3(t)$ are in the same plane as the circular plane formed by the 3 sensors (the x-y plane) and they can be decomposed to 2 orthogonal components h(t) and v(t) as shown in Figure 14. Mathematically this is $z_k(t) = \varepsilon_k(h(t)\cos(\theta_k) + v(t)\sin(\theta_k))$, where $h(t)$, v(t) are the motion signal being projected to horizontal and vertical directions and the direction of sensor k is θ_k from the horizontal direction and ε_k are coupling coefficients for the motion signal to the sensors. For the three detectors 120 degrees apart θ_k is 90, 210 and 330 degrees.

[0059] We can make the assuming that both γ_k,ε_k are much smaller than 1 and we can represent the received signal as DC and AC components($m_{ack}(t)$, $m_{dck}(t)$). By calculating the signal AC amplitude when there is no motion, we can normalize the 3 channels gain. Equations (1),(2),(3) can be approximated as :

$$(4)\quad m_{ac1}(t) = hb(t) + N'_{s1}(t) + N'_{f1}(t) + z_1'(t)$$

$$(5)\quad m_{ac2}(t) = hb(t) + N'_{s2}(t) + N'_{f2}(t) + z_2'(t)$$

$$(6)\quad m_{ac3}(t) = hb(t) + N'_{s3}(t) + N'_{f3}(t) + z_3'(t)$$

where $N'_{sk}(t)$, $N'_{fk}(t)$,$z_k'(t)$ are scaled versions of the original signals.

[0060] The signal due to heartbeat should have similar effect on the three signals 31, 32, 33 and should be in phase in each signal and differ only by a scaling factor. The sensors are placed evenly in a circle and so the effect of motion in x-y plane should be different for the 3 symmetrically located sensors. When there is no motion, or a very small amount of motion, the maximum signal to noise ratio (SNR) of the heartbeat signal can be obtained by adding up the three AC component input signal, i.e. $y(t) = m_{ac1}(t) + m_{ac2}(t) + m_{ac3}(t)$.

[0061] When there is exercise motion the noise signals $z_1'(t)$, $z_2'(t)$, $z_3'(t)$ become dominated in the received signals 31, 32, 33. We can solve this problem by finding the column vector

$$\hat{w} = \begin{bmatrix} w_1 & w_2 & w_3 \end{bmatrix}^T \text{ such that } \hat{y} = \hat{w}^T \mathrm{M}$$

where

$$\mathrm{M} = \begin{bmatrix} m_{ac1}[0] & m_{ac1}[1] & \Lambda & \Lambda & m_{ac1}[K-1] \\ m_{ac2}[0] & m_{ac2}[1] & \Lambda & \Lambda & m_{ac2}[K-1] \\ m_{ac3}[0] & m_{ac3}[1] & \Lambda & \Lambda & m_{ac3}[K-1] \end{bmatrix} \text{ and } \hat{y} = \begin{bmatrix} y[0] & y[1] & \Lambda & y[K-1] \end{bmatrix}.$$

and $\hat{y}$ is a linear combination of input signal which maximize :

$$\frac{\hat{w}^T \hat{s}\hat{s}^T \hat{w}}{\hat{w}^T \Re_{mm} \hat{w}}$$

where R_{mm} is the cross correlation matrix of the 3 signals from motion.

$$\hat{s} = \begin{bmatrix} s_1 & s_2 & s_3 \end{bmatrix}^T$$

is the corresponding gain of the heartbeat signal, in this case where all the 3 input channels are normalized.

$$\hat{s} = \begin{bmatrix} 1 & 1 & 1 \end{bmatrix}^T \text{ and } \Re_{mm} = \mathrm{MM}^T - \sigma^2 \hat{s}\hat{s}^T$$

where σ^2 is the variance of the heartbeat signal.

[0062] Since R_{mm} is positive definite, we can write :

$$\Re_{mm} = R^{\frac{1}{2}} \cdot R^{\frac{1}{2}} \text{ and we write } \hat{u} = R^{\frac{1}{2}} \hat{w}$$

$$\hat{w} = R^{-\frac{1}{2}} \hat{u}$$

[0063] The problem becomes :

$$\max_{\|\hat{u}\|=1} \hat{u}^T R^{-\frac{1}{2}} \hat{s} \cdot \hat{s}^T R^{-\frac{1}{2}} \hat{u}$$

or

$$\max_{\|\hat{u}\|=1} (\hat{u}^T R^{-\frac{1}{2}} \hat{s})^2$$

[0064] The expression is maximum when :

$$\hat{u} = R^{-\frac{1}{2}} \hat{s}$$

$$\therefore \hat{w} = R^{-\frac{1}{2}} (R^{-\frac{1}{2}} \hat{s}) = \Re_{mm}^{-1} \hat{s}$$

where

$$\Re_{mm} = \mathrm{MM}^T - \sigma^2 \hat{s}\hat{s}^T$$

[0065] The amplitude of 3 input heartbeat signal is normalized by calculating the variance (or standard deviation) of each channel when the user is not running.

[0066] Figure 15 schematically illustrates the processing of the sensor signals 31, 32, 33 to determine heartbeat. The following is a description of each block.

Block 71:

[0067] A simple Finite Input Response (FIR) low pass filter is used to remove all high frequency signals. Slow drifting DC offset is removed using a filter or a moving window to extract the DC offset and subtract back from the signal.

Block 72:

[0068] The signal amplitude of the heartbeat signal on each sensor is identified when there is no user motion. This is done by calculating the standard deviation of the 3 input signals when there is no motion. The 3 signal paths are then normalized.

Block 73:

[0069] We then determine whether there is motion. The signal are check in the time domain. If the heartbeat signal dominates, all the 3 signals should be synchronous and in-phase. If the motion of the user is big enough, it is expected that the signal from motion dominates and sensor signals should not be all in phase. The correlation index across the three signals is calculated. The amplitude of the signal when compared with rest time signal amplitude is a clear indicator for motion.

[0070] If there is no motion the three signals are added together (with normalized amplitude) to improve the SNR.

[0071] If there is motion : e.g. running, the acquired signals are cut into blocks of length K for calculating the covariance matrix

$$\Re_{mm} = \mathrm{MM}^T - \sigma^2 \hat{s}\hat{s}^T .$$

$\sigma^2 \hat{S}\,\hat{S}^T$ can be obtained calculating the standard deviation of the 3 input signals when there is no motion. The 3 input signals are then normalized to having signal standard deviation of σ when there is no motion. Then $\sigma^2 \hat{S}\,\hat{S}^T$ becomes

$$\sigma^2 \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

[0072] We then calculate the vector :

$$w = \Re_{mm}^{-1} \hat{s}$$

All 3 channels are calibrated and normalized when there is no motion

$$\hat{s} = \begin{bmatrix} 1 & 1 & 1 \end{bmatrix}^T$$

w is a 3x1 column vector :

$$\hat{y} = \hat{w}^T \mathrm{M}$$

y[n] is a linear combination of the 3 input signals
the signal due to motion should be canceled out and preserve the heartbeat signal

[0073] The linear combination may also be done in frequency domain as well. The time domain waveform can be restored using an inverse Fast Fourier Transform (FFT). The signal *y[n]* should contain the heartbeat signal + noise.

Block 74

[0074] The heartbeat signal is detected using match filters in the time domain. The user's resting heartbeat rate signal can be recorded as templates. The corresponding heart rate of these templates can be calculated and recorded as well. For each range of the heart rate, a template is stored for each user. For the range where there is no recorded template a time wrapping approach is used to predict an approximate template. These templates are then used to build multiple matched filters for the user. The corresponding matched filter will be selected according to current heartbeat rate of the user.

Block 76

[0075] The peaks of the matched filter output are detected and they are marked as the beat time. The inter-beat intervals are calculated and stored in a buffer.

Block 77

[0076] Based on the current beat rate, an algorithm was implemented to detect missed and false alarm of the beats. In case of a miss or false alarm the inter-beat intervals will be modified accordingly to improve accuracy of the heart rate calculation.

Block 78

[0077] The heart rate is then calculated from the inter-beat intervals buffer.

[0078] In addition to detecting the heart beat signal, a method is employed to extract the motion signal from the sensor signals. When the user is running, each of the input signals is the sum of the heart beat signal and the motion signal. Figure 16 shows the three sensor signals before and after the user starts to jog or run. Prior to running the three heart beat signals are in phase and of the same amplitude. When the user starts to jog or run the motion signals amplitude varies a lot among the three sensor signals. To accurately detect the step rate instead of the heart rate, it is necessary to remove the heart beat signal from the sensor signals. Step detection is activated only when it is determined that the user is running, which is described earlier. When user is running or jogging, the standard deviation of the three sensor signals is calculated for certain window width, typical 2 seconds. The standard deviation is use as a parameter representing the amplitude of the sensor signals. If the amplitude of the signal with the biggest amplitude is bigger than the rest time heart beat signal amplitude by certain ratio, in the preferred example 10, it is assumed that the motion signal completely dominates and this biggest emplitude signal is chosen as the motion signal, i.e.

$$y_{MOTION}(t) = m_{ac\_biggest}(t)$$

where $m_{ac-biggest}(t)$ is the input signal with biggest amplitude and the amplitude is bigger than the rest time heart beat signal by 10 times. If no sensor signal is ten times greater than the rest time heart beat signal, the standard deviation of the sensor signals are compared and ranked. The motion signals is the two biggest sensor signals minus two-times the smallest sensor signal, i.e.

$$y_{MOTION}(t) = m_{ac\_big1}(t) + m_{ac\_big2}(t) - 2m_{ac\_smallest}(t)$$

where m_{ac_big1}(t), m_{ac_big2}(t) are the 2 input signals with bigger amplitude and $m_{ac\_smallest}(t)$ is the input signal with smallest amplitude.

[0079] The reason for this simple formulation is that all the three sensor signals should contain a heart beat signal components with substantial identical amplitude. The components due to heart beat signal should cancel out most of the heart beat signal. The resultant motion signal, $y_{MOTION}(t)$, is a large amplitude sinusoidal signal with good signal to noise ratio and thus a simple zero crossing method can be used to determine the step counts when user is running: Suitable zero crossing methods should be well known in the art. Figure 17 is a flow chart of this method.

[0080] In order to determine distance run the distance per step must be known for the particular user. This can be input manually by user if they know or can calculate their typical stride length, or the device can be put in to calibration mode which requires the user to walk and run for a certain distance. Figure 18 shows the relationship of the step distance and the rate of steps. The data point will then be used to interpolate or extrapolate the cure of step distance versus rate of step. After the steps are detected, the rate of the step and the number of step will be calculated. The rate of steps will be used to estimate the distance traveled of each steps. The step distance is accumulated and will be recorded as the total workout distance traveled when the workout is finished.

[0081] The exercise device processes, displays and stores health related data, such as heart rate, blood oxygen level (Sp02), body temperature, steps walked or run, entered weight to calculate calories burned and body mass index (BMI). The user connects to the headphones that not only playback audio files but also simultaneously captures end users health related data inside the ear. The data is transferred to the portable entertainment device and workout assistant for processing, displaying/notifying and storing the data.

[0082] The following various functions are available on the device. This is, however, not an exhaustive list and more or less features may be included in some embodiments.

[0083] Preferred features include;-

1. Playback of the audio/video files stored on the device,
2. Determining and displaying the instantaneous heart rate and storing a heart rate profile during an exercise period.
3. Storing and displaying the number of steps taken.
4. Determining, displaying and storing the health related status of the end user, including temperature, blood oxygen level and other body parameters.
5. Providing visual and audio feedback of target exercise parameters and/or rates to help the end user optimize his physical activity - for example a pre approved beep as a sign to slow down, a pre approved different signal/sound for signaling end user to pick up the pace and a pre defined sound for providing signal on what percentage of the exercise has been completed.
6. Transfer of date to a PC for further analysis, review or summary,
7. Providing visual and audio feedback, for example via pause or stop playback, if the device detects one or more of the ear buds is not capturing a heartbeat which mean a possible detach and resume playback after the device detects a heartbeat from one or both of the ear buds.
8. Providing visual and audio feedback of target exercise parameters by changing the tempo, pitch, equalizer according to the inputted vital sign so as to raise or reduce the workout intensity of the user sub-consciously - Figures 19 and 20 shows the block diagram of the way to implement the change of audio signal based on vital sign.
9. Providing visual and audio feedback of target exercise distance by changing the temp, pitch, equalizer according to the inputted step rate and distance traveled.

Claims

1. A noninvasive light sensor for detecting heart beat signals, comprising:

   a circular support member engageable circumferentially with a body part of a person,
   a plurality of light emitters located about a circumference of the circular support member for emitting light signals into different areas of tissue surrounding the body part, and
   a plurality of light detectors located about a circumference of the circular support member for receiving reflected light signals from the different areas of tissue surrounding the body part.

2. The noninvasive light sensor of claim 1 wherein plurality of light emitters consist of three light emitters located 120 degrees apart about the circumference of the support member.

3. The noninvasive light sensor of claims 1 or 2 wherein the plurality of light detectors consist of three light detectors located 120 degrees apart about the circumference of the support member.

4. The noninvasive light sensor of any preceding claim wherein the light emitters and light detectors are located in pairs consisting of one of the emitters and one of the detectors.

5. The noninvasive light sensor of any preceding claim wherein the circular support member being an ear bud insertable with the an ear canal along an ear canal axis, wherein the plurality of light emitters are located about the periphery of the ear piece for emitting light signals perpendicular to the ear canal axis into the different areas of tissue surrounding the ear canal, and the plurality of light detectors are located about the periphery of the ear piece for receiving reflected light signals from the different areas of tissue surrounding the ear canal.

6. The noninvasive light sensor of claim 5 wherein the ear piece is resiliently deformable for expansion within the ear canal, such that the ear piece is firmly locatable within the ear canal.

7. The noninvasive light sensor of claims 5 or 6 wherein the ear price comprises an inner layer and an outer layer having a plurality of openings, the light emitters and light detectors located within the outer layer openings.

8. The noninvasive light sensor of claim 7 wherein the openings have light absorbent sides surrounding the light emitters and light detectors, the sides defining a narrow gap above the light emitters and light detectors.

9. The noninvasive light sensor of claim 1 wherein the support member comprising a band locatable about a wrist or arm, the emitters and detectors located around an inner circumference of the band for respectively emitting light signals into the different areas of arm tissue and receiving reflected light from the different areas of arm tissue.

10. A exercise system comprising:

an ear piece insertable within an ear canal along a canal axis, the ear piece having a plurality of light sensors and detectors, and a audio speaker,
a computer readable storage medium have space allocated for storage of audio files,
a vital sign monitor programmed to generating a vital sign signal from signals of the emitters and detectors, and
an audio player programmed to playback audio files thought the audio speaker in response to the vital sign signal and to vary attributes of the playback audio files in response to the vital sign signal.

11. The exercise system of claim 10 wherein the attributes of the playback audio files to be varied include one or more of beat, tempo, tone, pitch and the audio filed being played.

12. The exercise system of claims 10 or 11 wherein the vital sign monitor is programmed to generating a heart rate, blood oxygen or temperature signal.

13. A method of determining heart rate of a person during exercise comprising:

obtaining a plurality of sensor signals from multiple locations about a body part of a person, the sensor signals comprising a heart beat signals and a movement signals,
comparing the signals to separate the heart beat signals and a movement signals, and
determining heart rate from the heart beat signals.

14. The method of claim 13 wherein obtaining a plurality of sensor signals from locations comprises providing a plurality of heart beat sensors for positioning at multiple locations about the body part.

15. The method of claims 13 or 14 wherein comparing the signals to separate the heart beat signals and a movement signals comprises comparing the sensor signals to find in phase and out of phase components of the sensor signals.

16. The method of any one of claims 13 to 15 wherein comparing the signals to separate the heart beat signals and a movement signals comprises finding a covariance between the sensor signals.

17. The method of any one of claims 13 to 16 wherein determining heart rate from the heart beat signals comprises using match filters.

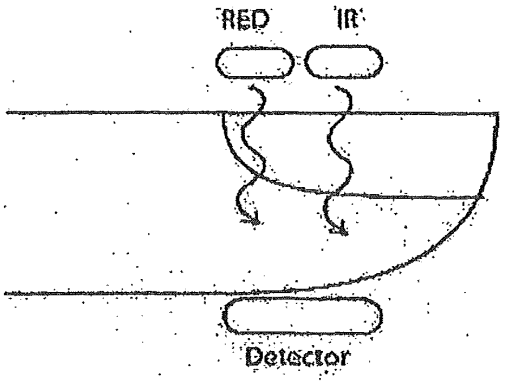


Figure 1 (Prior Art)

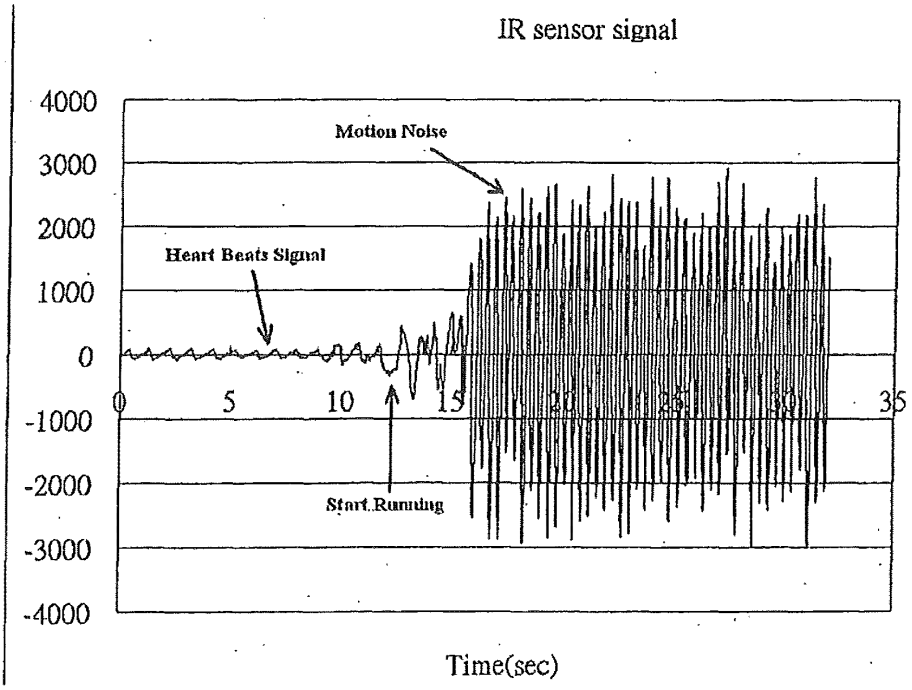
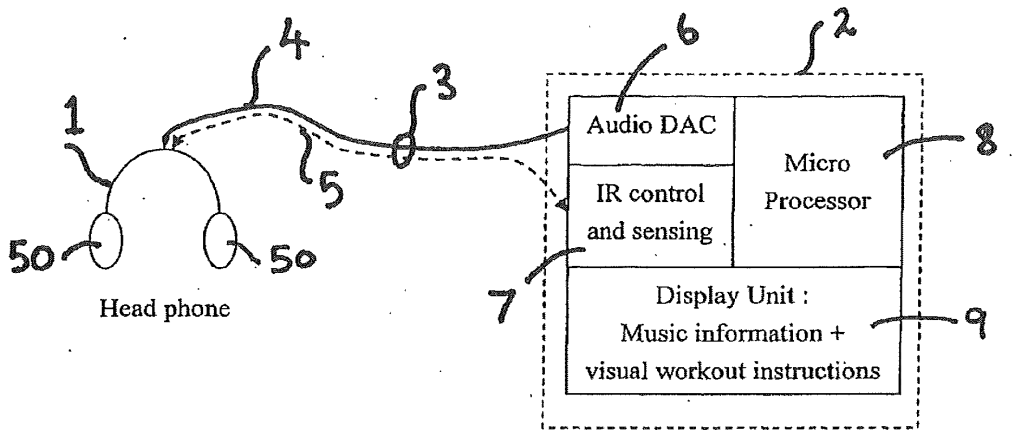


Figure 2 (Prior Art)



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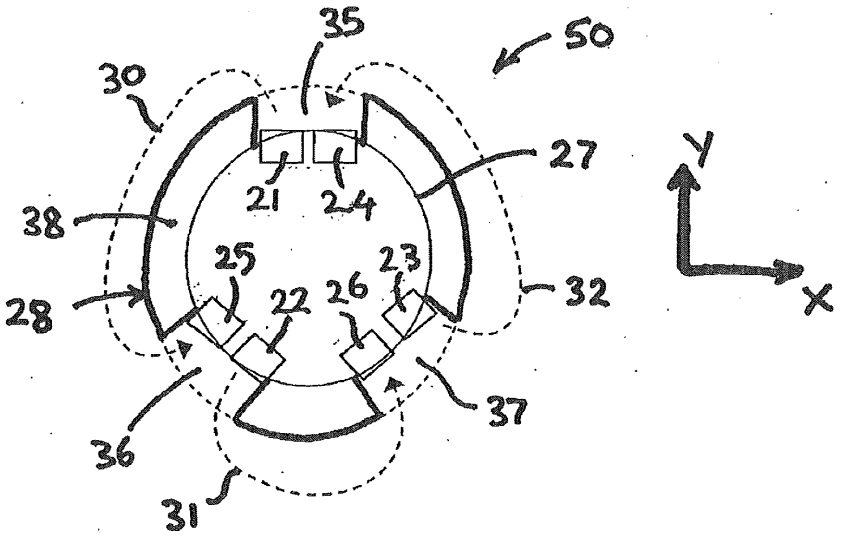

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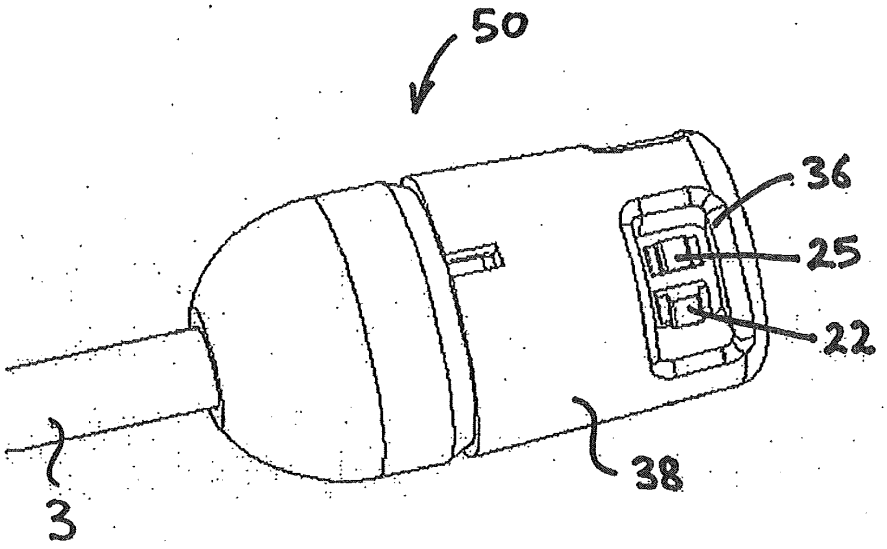

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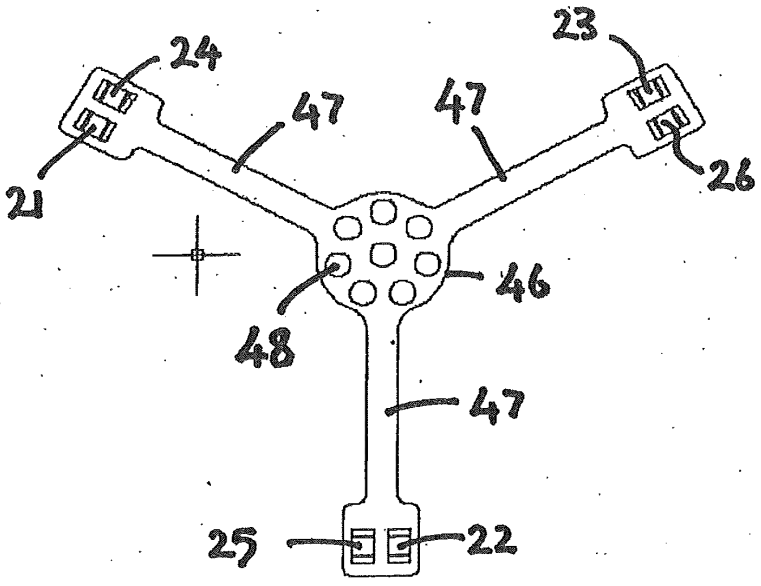

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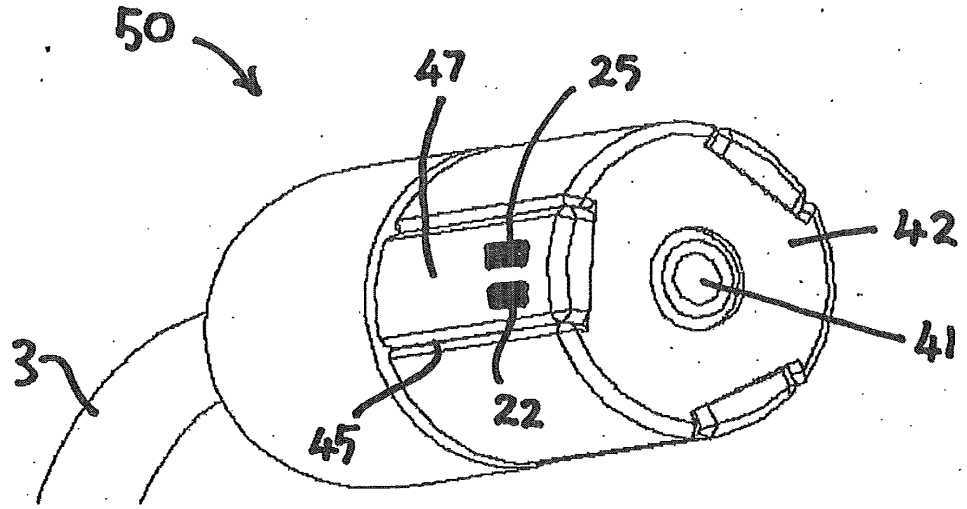

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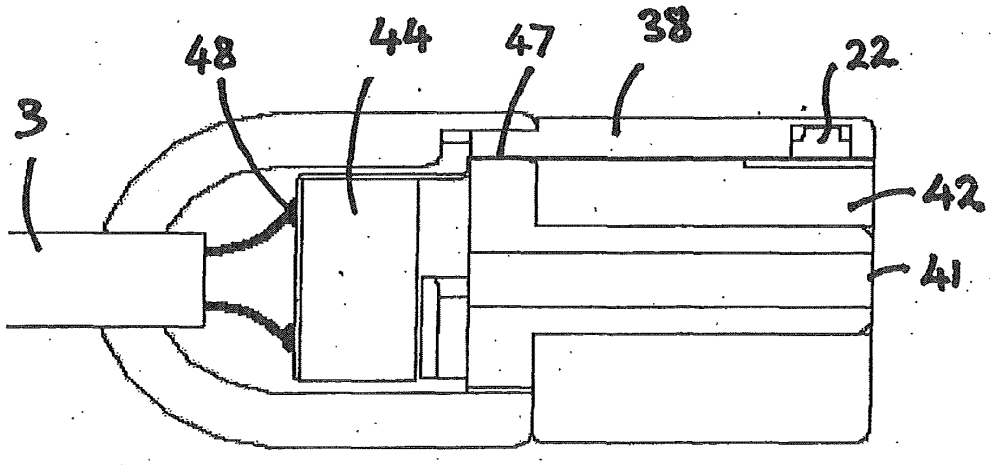

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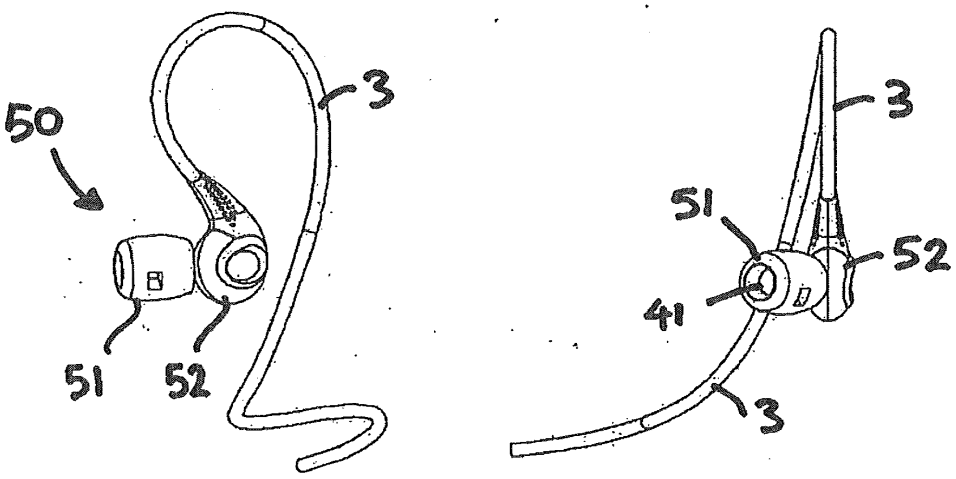

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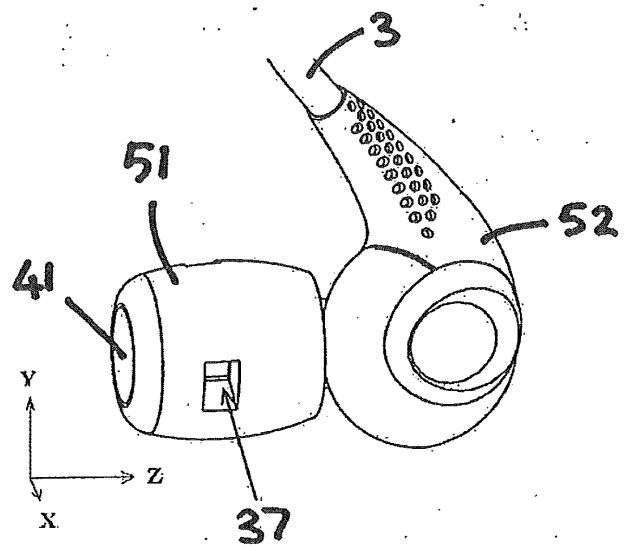

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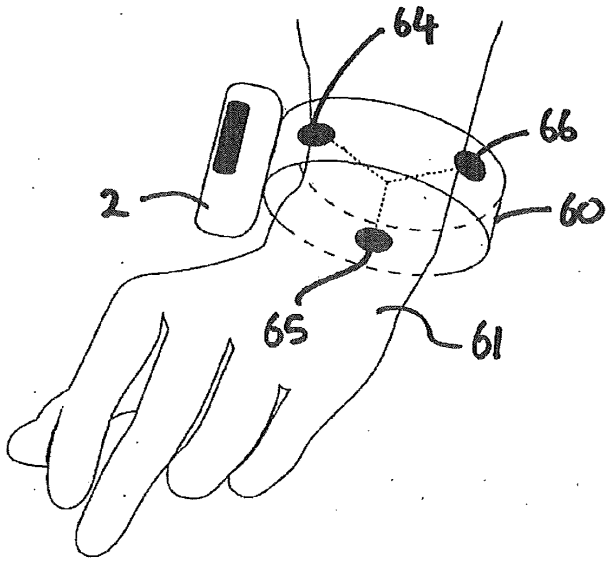

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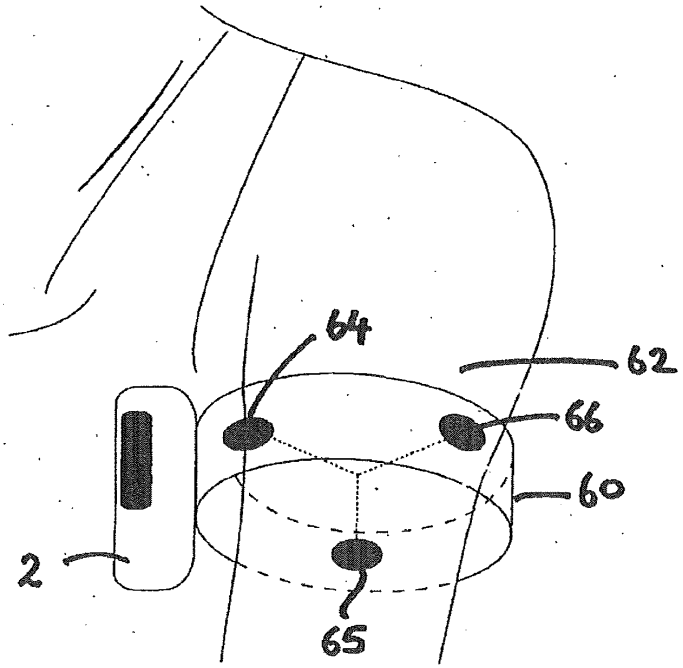

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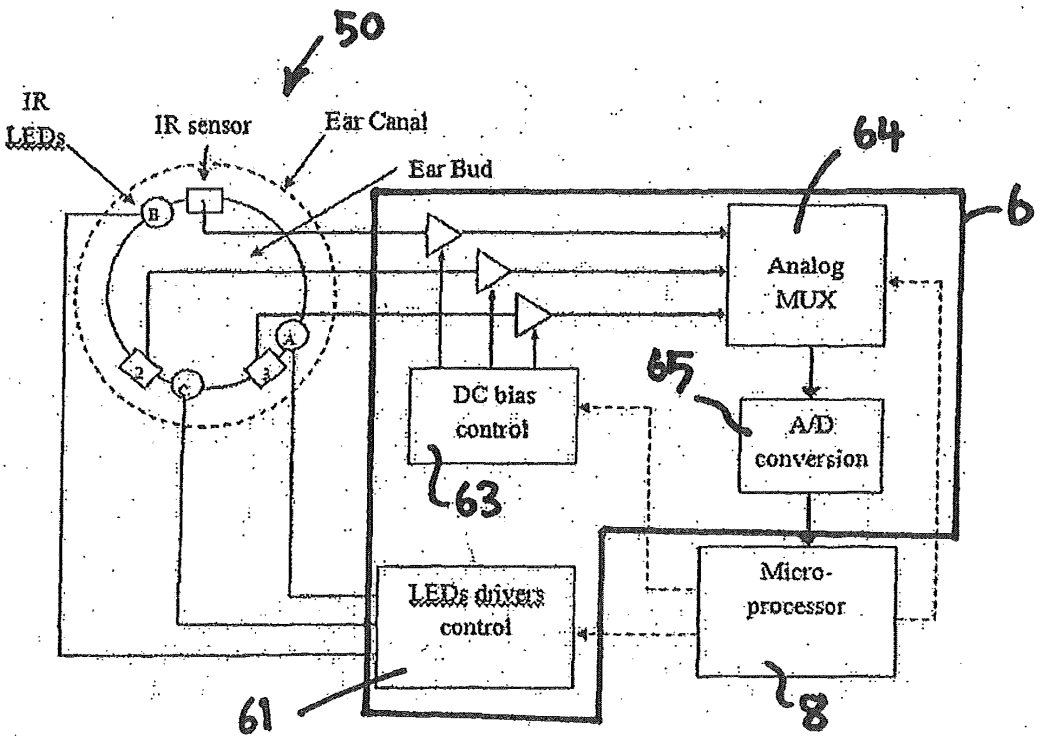

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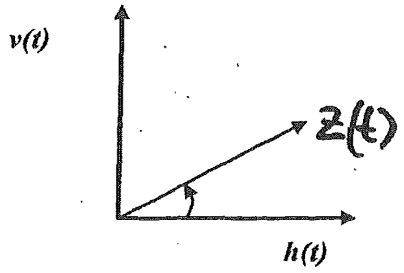

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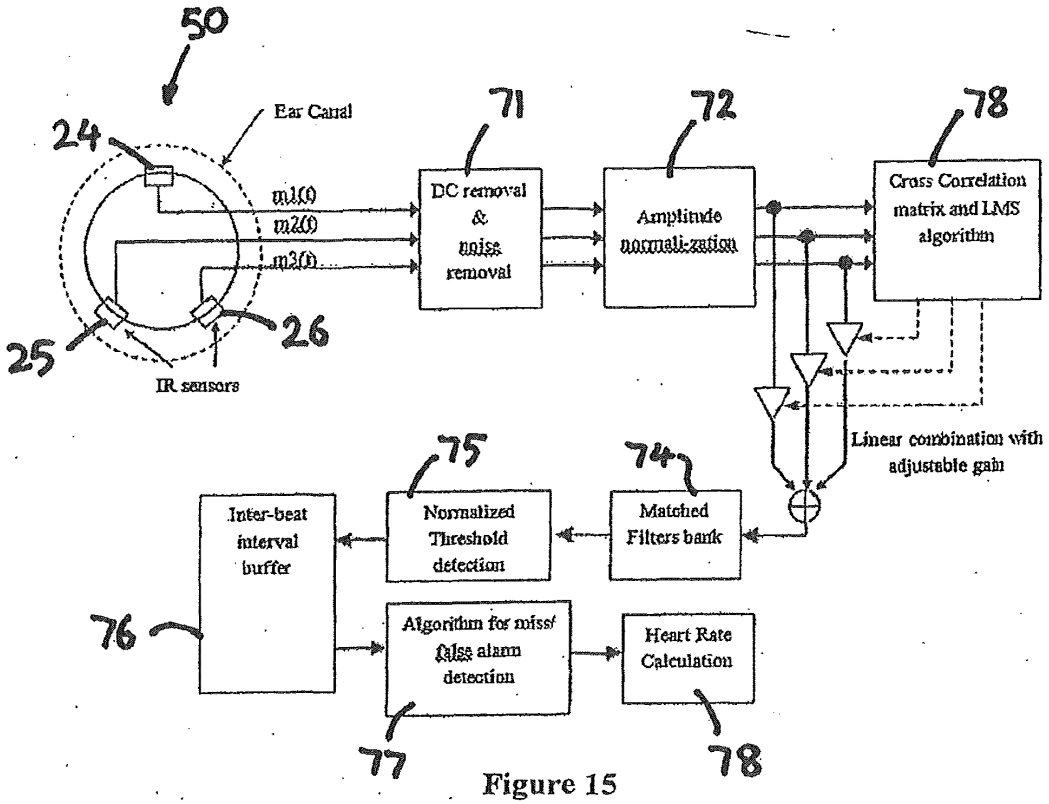

Figure 15

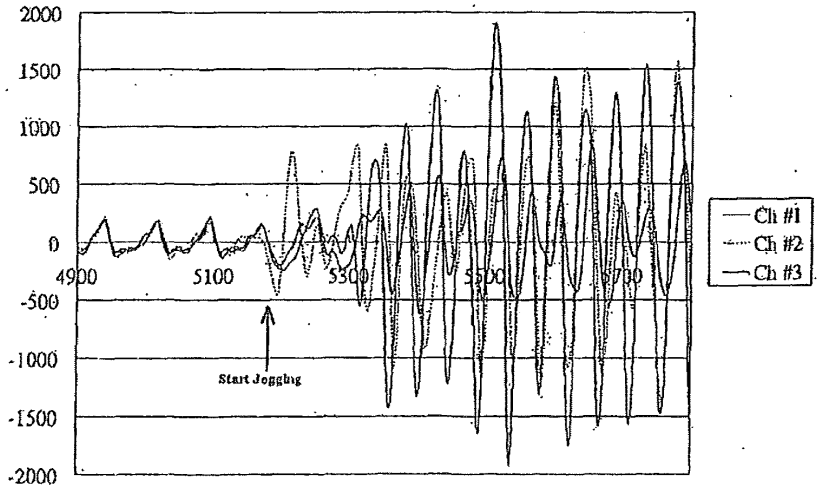

Figure 16

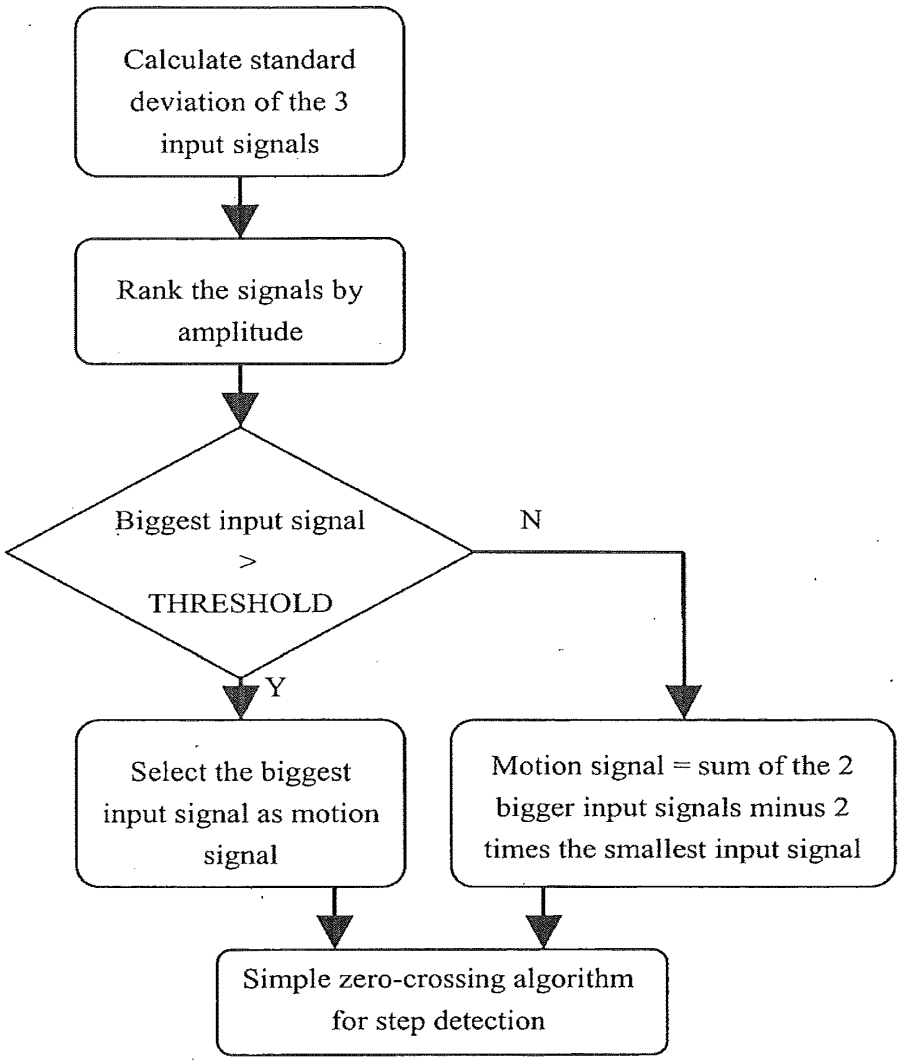

Figure 17

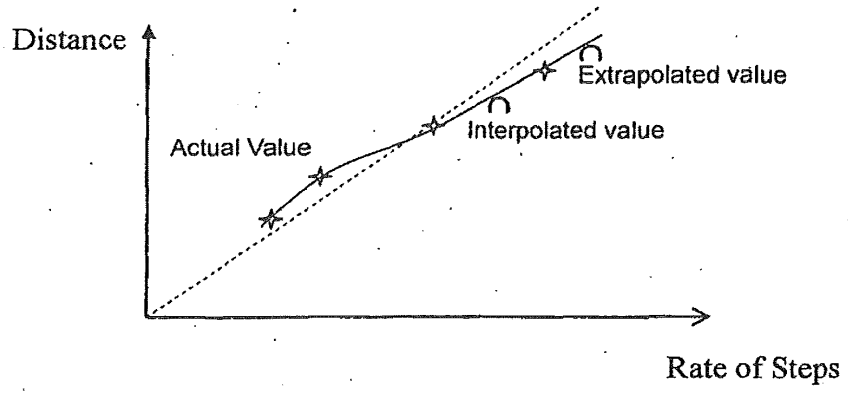

Figure 18

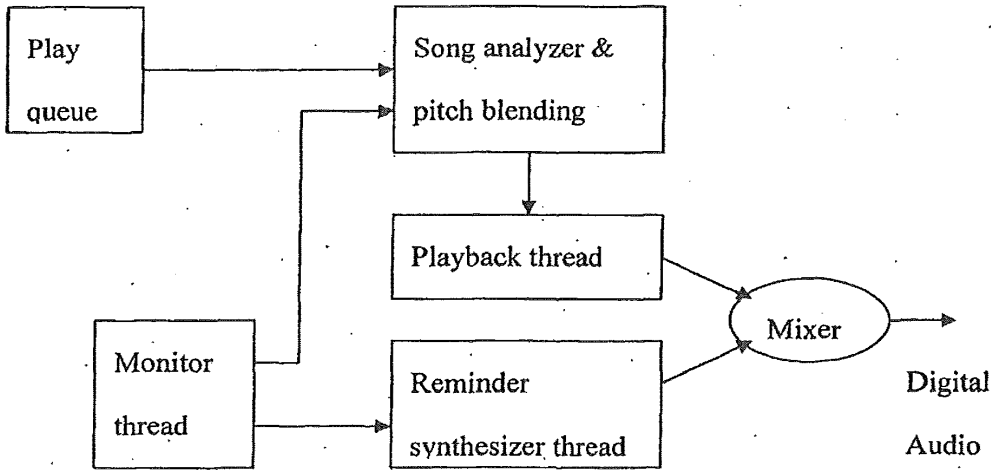

Figure 19

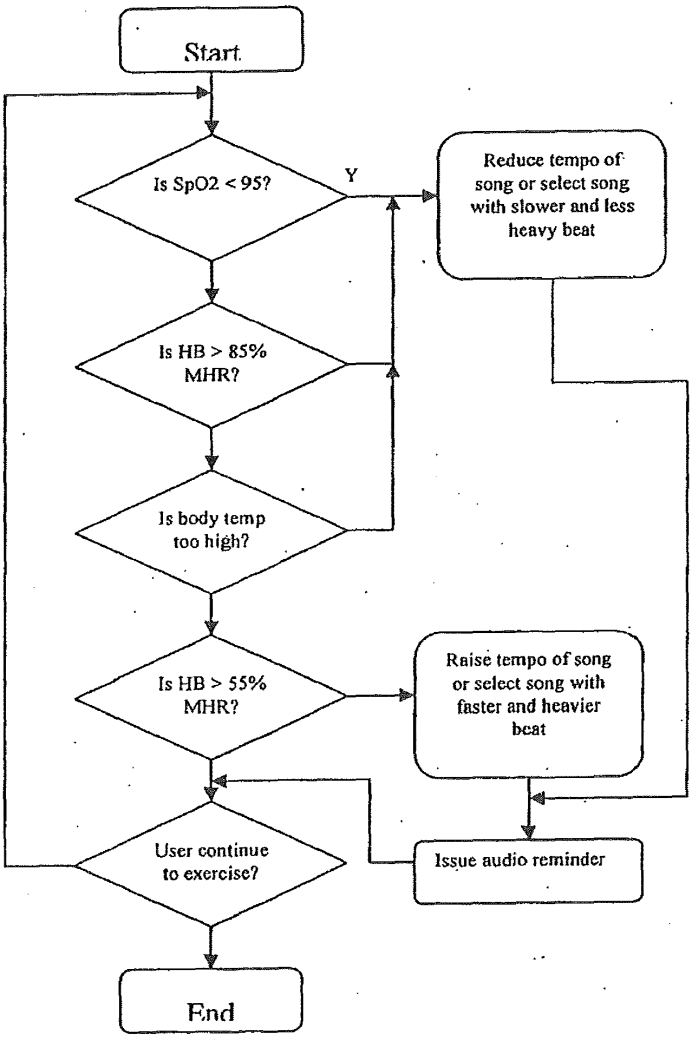

Figure 20

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- **M.R. Neuman ; N. Wang.** Motion Artifact in Pulse Oximetry. *Annual International Conference of the IEEE Engineering in Medicine and Biology Society,* 1990, vol. 12 (5 **[0006]**

Electronic Patent Application Fee Transmittal

Application Number:	14274288
Filing Date:	09-May-2014
Title of Invention:	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME
First Named Inventor/Applicant Name:	Steven Francis LeBoeuf
Filer:	Needham J. Boddie/Susan E. Freedman
Attorney Docket Number:	9653-7IPCT

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Submission- Information Disclosure Stmt	1806	1	180	180
		Total in USD ($)		**180**

Electronic Acknowledgement Receipt

EFS ID:	19967437
Application Number:	14274288
International Application Number:	
Confirmation Number:	9722
Title of Invention:	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME
First Named Inventor/Applicant Name:	Steven Francis LeBoeuf
Customer Number:	20792
Filer:	Needham J. Boddie/Susan E. Freedman
Filer Authorized By:	Needham J. Boddie
Attorney Docket Number:	9653-7IPCT
Receipt Date:	26-AUG-2014
Filing Date:	09-MAY-2014
Time Stamp:	14:26:30
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$180
RAM confirmation Number	678
Deposit Account	500220
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

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	Specification	2	2
	Claims	3	7
	Applicant Arguments/Remarks Made in an Amendment	8	16

Warnings:					
Information:					
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	Document Description	**Start**	**End**
	Transmittal Letter	1	2
	Information Disclosure Statement (IDS) Form (SB08)	3	3

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

Attorney Docket No.: 9653-7IPCT **PATENT**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re: LeBoeuf et al. Confirmation No.: 9722

Serial No.: 14/274,288 Group Art Unit: 2852

Filed: May 9, 2014 Examiner: Rodney Evan Fuller

For: **LIGHT GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME**

Date: August 26, 2014

Mail Stop Amendment
Commissioner for Patents
P. O. Box 1450
Alexandria, VA 22313-1450

RESPONSE TO OFFICE ACTION OF AUGUST 12, 2014

Applicants provide the present Response to address the issues raised in the Office Action (the "Action") mailed August 12, 2014. Applicants provide the present Response pursuant to the rules stated in revised 37 C.F.R. 1.121 that became effective on July 30, 2003.

It is not believed that an extension of time and/or additional fee(s)-including fees for net addition of claims-are required, beyond those that may otherwise be provided for in documents accompanying this paper. In the event, however, that an extension of time is necessary to allow consideration of this paper, such an extension is hereby petitioned under 37 C.F.R. §1.136(a). Any additional fees believed to be due in connection with this paper may be charged to our Deposit Account No. 50-0220.

Amendments to the Specification begin on Page 2 of this paper.

Amendments to the claims begin on Page 3 of this paper.

Remarks begin on Page 8 of this paper.

In the Specification:

Please amend the paragraph beginning on page 5, line 3 of the specification as follows:

-- In some embodiments, an earbud includes at least one lens in optical communication with the light transmissive material. Each lens may be configured to focus light from the optical emitter onto one or more predetermined locations in the ear of a subject and/or to focus collected external light onto the optical detector. --

Please amend the paragraph beginning on page 16, line 27 of the specification as follows:

-- Fig. 6 is a side section view of a light-guiding earbud for a headset, according to some embodiments of the present invention.[[.]] --

This listing of claims replaces all prior versions in the application.

Listing of Claims:

1. (Currently Amended) A sensor module for detecting and/or measuring physiological information from a subject, the sensor module comprising:

a housing;

at least one optical emitter supported by the housing;

at least one optical detector supported by the housing;

a first light guide supported by the housing, wherein the first light guide is in optical communication with the at least one optical emitter, wherein the first light guide comprises a distal end having an exposed end surface that is configured to engage a portion of a body of the subject, and wherein the first light guide is configured to deliver light from the at least one optical emitter directly into the [[a]] body of the subject via the exposed ~~distal~~ end surface thereof; and

a second light guide supported by the housing, wherein the second light guide is in optical communication with the at least one optical detector, wherein the second light guide comprises a distal end having an exposed end surface that is configured to engage a portion of the body of the subject, and wherein the second light guide is configured to collect light directly from the body of the subject via the ~~distal~~ exposed end surface thereof and deliver collected light to the at least one optical detector.

2. (Original) The sensor module of Claim 1, wherein the housing is configured to be integrated within an audio headset, a wrist strap, a wrist watch, an ankle bracelet, or an armband.

3. (Original) The sensor module of Claim 1, further comprising at least one motion sensor supported by the housing, wherein the at least one motion sensor is configured to sense motion information from the subject.

4. (Original) The sensor module of Claim 3, further comprising at least one processor supported by the housing, wherein the at least one processor is configured to

remove motion artifacts from signals produced by the at least one optical detector in response to signals produced by the at least one motion sensor.

5. (Original) The sensor module of Claim 1, wherein the first light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by first light guide.

6. (Original) The sensor module of Claim 1, wherein the second light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by second light guide.

7. (Original) The sensor module of Claim 1, wherein at least one of the first and second light guides comprises elastomeric light transmissive material.

8. (Original) The sensor module of Claim 1, wherein at least one of the first and second light guides comprises substantially rigid light transmissive material.

9. (Original) The sensor module of Claim 1, wherein the at least one optical emitter comprises optical coupling material, and wherein the first light guide is in optical communication with the at least one optical emitter via the optical coupling material.

10. (Original) The sensor module of Claim 1, wherein the at least one optical detector comprises optical coupling material, and wherein the second light guide is in optical communication with the at least one optical detector via the optical coupling material.

11. (Original) The sensor module of Claim 3, further comprising at least one processor supported by the housing, wherein the at least one processor is configured to process signals produced by the at least one optical detector and signals produced by the at least one motion sensor to determine subject heart rate and respiration rate.

12. (Currently Amended) A sensor module for detecting and/or measuring physiological information from a subject, the sensor module, comprising:

a housing;

at least one optical emitter supported by the housing;

at least one optical detector supported by the housing;

a first light guide supported by the housing, wherein the first light guide is in optical communication with the at least one optical emitter, and wherein the first light guide is configured to deliver light from the at least one optical emitter into a body of the subject;

a second light guide supported by the housing, wherein the second light guide is in optical communication with the at least one optical detector, and wherein the second light guide is configured to collect light from the body of the subject;

a motion sensor supported by the housing, wherein the motion sensor is configured to sense motion information from the subject; and

a processor supported by the housing, wherein the processor is configured to remove motion artifacts from signals produced by the at least one optical detector in response to signals produced by the motion sensor, and wherein the processor is configured to process signals produced by the at least one optical detector to determine a plurality of physiological parameters, comprising two or more of the following: subject heart rate, ~~and~~ respiration rate, blood flow, heart rate variability, and blood gas level.

13. (Original) The sensor module of Claim 12, wherein the housing is configured to be integrated within an audio headset, a wrist strap, a wrist watch, an ankle bracelet, or an armband.

14. (Currently Amended) The sensor module of Claim 12, wherein one or both of the first and second light guides comprises optical dye that is configured to filter one or more wavelengths of light ~~guided by first light guide~~.

15. (Currently Amended) The sensor module of Claim 12, wherein the ~~second light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by second light guide~~ processor utilizes at least one digital filter and at least one peak finding algorithm to process signals produced by the at least one optical detector to determine the plurality of physiological parameters.

16. (Original) The sensor module of Claim 12, wherein at least one of the first and second light guides comprises elastomeric light transmissive material.

17. (Original) The sensor module of Claim 12, wherein at least one of the first and second light guides comprises substantially rigid light transmissive material.

18. (Currently Amended) The sensor module of Claim 12, wherein the at least one optical emitter comprises optical coupling material, and wherein the first light guide is in optical communication with the at least one optical emitter via the optical coupling material, and/or wherein the at least one optical detector comprises optical coupling material, and wherein the second light guide is in optical communication with the at least one optical detector via the optical coupling material.

19. (Currently Amended) The sensor module of Claim 12, wherein the ~~at least one optical detector comprises optical coupling material, and wherein the second light guide is in optical communication with the at least one optical detector via the optical coupling material~~ processor is configured to process signals produced by the at least one optical detector to determine all of the following: subject heart rate, respiration rate, blood flow, heart rate variability, and blood gas level.

20. (Currently Amended) A sensor module for detecting and/or measuring physiological information from a subject, the sensor module, comprising:

a housing;

an optical emitter supported by the housing;

an optical detector supported by the housing;

a first light guide supported by the housing, wherein the first light guide is in optical communication with the optical emitter, wherein the first light guide comprises a distal free end having an exposed end surface that is configured to engage a portion of a body of the subject, and wherein the first light guide is configured to deliver light from the optical emitter directly into the [[a]] body of the subject via the exposed ~~distal~~ end surface thereof; and

a second light guide supported by the housing, wherein the second light guide is in optical communication with the optical detector, wherein the second light guide comprises a

distal free end having an exposed end surface that is configured to engage a portion of the body of the subject, and wherein the second light guide is configured to collect light directly from the body of the subject via the ~~distal~~ exposed end surface thereof and deliver collected light to the optical detector,

wherein the distal free ends of the first and second light guides are in adjacent, spaced-apart relationship.

REMARKS

Claims 1-20 are pending.

Claims 1, 2, 7-10 and 20 stand rejected under 35 U.S.C. §102(b) as being anticipated by U.S. Patent No. 7,107,088 to Aceti ("Aceti").

Claims 3, 4, 11-13 and 16-19 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Aceti in view of U.S. Patent No. 8,055,319 to Oh et al. ("Oh").

Claims 5, 6, 14 and 15 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Aceti in view of U.S. Patent No. 6,078,829 to Uchida et al. ("Uchida").

Claims 1-20 stand rejected on the ground of nonstatutory double patenting as being unpatentable over Claims 1-30 of U.S. Patent No. 8,788,002.

Claims 1-20 stand rejected on the ground of nonstatutory double patenting as being unpatentable over Claims 1-42 of U.S. Patent No. 8,700,111.

Claims 1-20 stand provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over Claims 1-20 of co-pending U.S. Patent Application No. 14/298,219.

Claims 1-20 stand provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over Claims 1-21 of co-pending U.S. Patent Application No. 14/298,402.

Claims 1-20 stand provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over Claims 1-42 of co-pending U.S. Patent Application No. 14/184,364.

Claims 1-20 stand provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over Claims 1-20 of co-pending U.S. Patent Application No. 14/194,891.

Applicants have amended Claims 1, 12, 14, 15, 18, 19 and 20, as indicated above, for clarification.

Applicants respectfully traverse the double patenting rejections and the rejections under §102 and §103 for at least the reasons described herein.

Specification

Applicants have amended the Specification, as indicated above, to correct several typographical errors.

Section 102 Rejections

Claims 1, 2, 7-10 and 20 stand rejected under 35 U.S.C. §102(b) as being anticipated by U.S. Patent No. 7,107,088 to Aceti ("Aceti"). Applicants respectfully traverse the rejection because Aceti does not teach or suggest all of the recitations of amended independent Claims 1 and 20. For example, amended independent Claim 1 recites a sensor module for detecting and/or measuring physiological information from a subject, the sensor module comprising:

> a housing;
> at least one optical emitter supported by the housing;
> at least one optical detector supported by the housing;
> a first light guide supported by the housing, wherein the first light guide is in optical communication with the at least one optical emitter, wherein the first light guide comprises a distal end having an exposed end surface that is configured to engage a portion of a body of the subject, and wherein the first light guide is configured to deliver light from the at least one optical emitter directly into the body of the subject via the exposed end surface thereof; and
> a second light guide supported by the housing, wherein the second light guide is in optical communication with the at least one optical detector, wherein the second light guide comprises a distal end having an exposed end surface that is configured to engage a portion of the body of the subject, and wherein the second light guide is configured to collect light directly from the body of the subject via the exposed end surface thereof and deliver collected light to the at least one optical detector.

Figs. 24A and 25A from Applicants' application are set forth below and illustrate exemplary sensor modules 10 as recited in Claim 1.

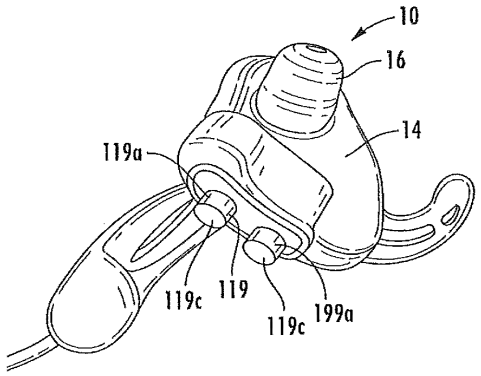


FIG. 24A

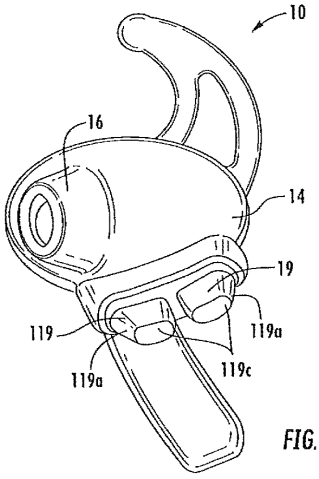


FIG. 25A

Figs. 24A and 25A illustrate headsets 10 having light guides 119 that are optically coupled with one or more optical emitters and optical detectors. Each illustrated headset 10 includes a housing 14 that is configured to be supported within an ear of a person and that encloses and protects various electronic components including the at least one optical emitter and the at least one optical detector. Each light guide 119 includes a distal end portion 119a and an opposite proximal end portion. The distal end 119a of each light guide 119 has an exposed end surface 119c that is configured to engage (or be positioned adjacent) a portion of an ear of a subject. The opposite proximal end of each light guide 119 is in optical communication with a respective optical emitter and optical detector. As such, a respective light guide 119 is configured to deliver light from an optical emitter into an ear region of the subject via the distal end exposed surface 119c, and a respective light guide 119 is configured to collect light from an ear region of the subject via the distal end exposed surface 119c and deliver collected light to the optical detector 26. (Specification, page54, line 1 – page 55, line 27.)

Aceti describes an oximetry sensor 200 that is configured to measure oxygen saturation levels in the vascular tissue 29 within the third region 25 of the auditory canal 100. (Aceti, col. 2, lines 60-64.) Fig. 2 from Aceti is set forth below and illustrates the oximetry sensor 200.

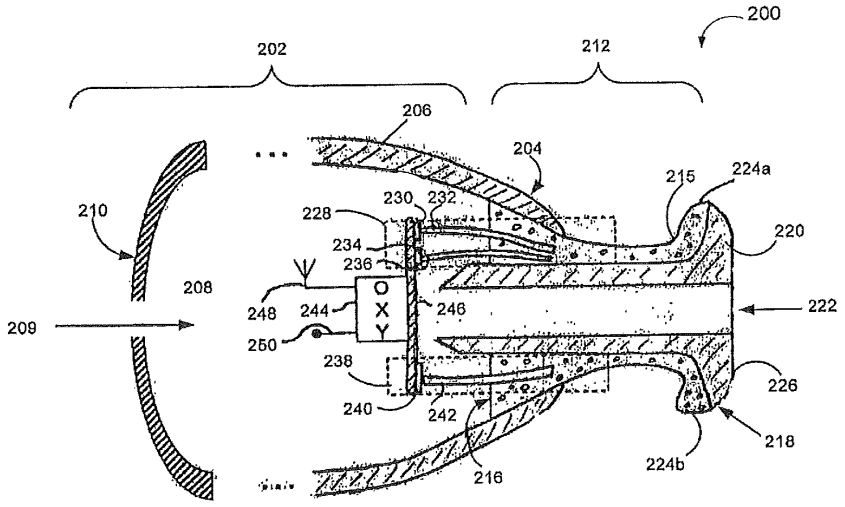


FIG. 2

A first portion 202 of the oximetry sensor 200 is configured for placement in the second region 23 of the auditory canal 100, and includes a distal end 204 that extends toward the tympanic membrane 26 when the oximetry sensor 200 is positioned within the auditory canal 100. (Aceti, col. 2, line 64 – col. 3, line 3.) A second portion 212 of the oximetry sensor 200 is configured for placement in the third region 25 of the auditory canal 100, and includes optically transparent portions 224 and optically blocking portions 226 for use in measuring oximetry levels within the vascular tissue 29 of the third region 25. (Aceti, col. 3, lines 52-58.) The optically transparent portions 224 form channels and/or islands within the optically blocking portions 226. (Aceti, col. 3, lines 59-61.)

An emitter 228 is positioned within the oximetry sensor 200 to emit light of two or more wavelengths from a first optically transparent portion 224a of the second portion 212 into a corresponding first position of the vascular tissue 29 when the oximetry sensor 200 is positioned within the auditory canal 100. (Aceti, col. 4, lines 56-61.) The illustrated emitter 228 includes a first light source 230, a first light channel 232, a second light source 234, and a second light channel 236. (Aceti, col. 4, lines 61-64.) The first and second light channels 232 and 234 are configured to direct light from the first and second light sources, respectively, to the first optically transparent portion 224a. (Aceti, col. 4, line 66 – col. 5, line 2.)

A detector 238 is positioned within the oximetry sensor 200 to detect light of the two or more wavelengths out of a second position of the vascular tissue 29 impinging a corresponding second optically transparent portion 224b of the second portion 212 when the oximetry sensor 200 is positioned within the auditory canal 100. (Aceti, col. 5, lines 11-16.) The detector 238 includes a photodetector 240 and a third light channel 242 (e.g., an optical fiber) that is configured to direct light impinging the second optically transparent portion 224b of the second portion 212 through the second portion 212 to the photodetector 240. (Aceti. col. 4, lines 16-24.)

Clearly, the distal ends of the first, second and third light channels 232, 236 and 242 terminate ***within*** the optically transparent material 224a, 224b of the device 200 and do not have exposed end surfaces that engage the ear canal tissue of a subject. It is the separate, optically transparent material 224a, 224b that engages the ear canal tissue. As such, Aceti fails to teach or suggest "wherein the first light guide comprises a distal end having an exposed end surface that is configured to engage a portion of a body of the subject" and

"wherein the second light guide comprises a distal end having an exposed end surface that is configured to engage a portion of the body of the subject," as recited in Claim 1. Moreover, Aceti fails to teach or suggest "wherein the first light guide is configured to deliver light from the at least one optical emitter ***directly into the body of the subject via the exposed end surface*** thereof" and "wherein the second light guide is configured to ***collect light directly from the body of the subject via the exposed end surface*** thereof and deliver collected light to the at least one optical detector," as recited in Claim 1. Because Aceti fails to teach or suggest all of the recitations of Claim 1, Claim 1 is not anticipated by Aceti and the rejection of independent Claim 1 under 35 U.S.C. §102 is overcome. Additionally, dependent Claims 4-10 are patentable at least by virtue of the patentability of independent Claim 1, from which they depend.

Amended independent Claim 20 contains similar recitations as amended independent Claim 1. Thus, for at least the same reasons set forth above with respect to Claim 1, Claim 20 is not anticipated by Aceti and the rejection of independent Claim 20 under 35 U.S.C. §102 is overcome.

Section 103 Rejections

a) Claims 12 and 16-19

Independent Claim 12 stands rejected under 35 U.S.C. §103(a) as being unpatentable over Aceti in view of Oh. Applicants respectfully traverse the rejection because Aceti and Oh, alone or in combination, do not teach or suggest all of the recitations of amended independent Claim 12. For example, amended independent Claim 12 recites a sensor module for detecting and/or measuring physiological information from a subject, comprising:

> a housing;
> at least one optical emitter supported by the housing;
> at least one optical detector supported by the housing;
> a first light guide supported by the housing, wherein the first light guide is in optical communication with the at least one optical emitter, and wherein the first light guide is configured to deliver light from the at least one optical emitter into a body of the subject;
> a second light guide supported by the housing, wherein the second light guide is in optical communication with the at least one optical detector, and wherein the second light guide is configured to collect light from the body of the subject;
> a motion sensor supported by the housing, wherein the motion sensor is configured to sense motion information from the subject; and

> a processor supported by the housing, wherein the processor is configured to remove motion artifacts from signals produced by the at least one optical detector in response to signals produced by the motion sensor, and ***wherein the processor is configured to process signals produced by the at least one optical detector to determine a plurality of physiological parameters, comprising two or more of the following: subject heart rate, respiration rate, blood flow, heart rate variability, and blood gas level.***

The Examiner concedes that the sensor of the primary reference, Aceti, fails to include a processor. (Action, page 4.) The secondary reference, Oh, is only cited for disclosing a motion sensor and a processor configured to remove motion artifacts. (Action, page 4.) Neither Aceti nor Oh teach or suggest a sensor module having a processor that is configured to process signals produced by an optical detector to determine a plurality of physiological parameters, comprising ***two or more of the following: subject heart rate, respiration rate, blood flow, heart rate variability, and blood gas level***, as recited in amended Claim 12. As such, Claim 12 is patentable and the rejection of Claim 12 under §103 is overcome. Additionally, dependent Claims 13-19 are patentable at least by virtue of the patentability of independent Claim 1, from which they depend.

b) Claims 3, 4 and 11

Claims 3, 4 and 11 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Aceti in view of Oh. Claims 3, 4 and 11 depend from independent Claim 1. Independent Claims 1 is patentable over Aceti for at least the reasons discussed above. The secondary reference, Oh, fails to rectify the deficiencies of Aceti with respect to independent Claim 1. Oh is only cited for disclosing a motion sensor and processor. (Action, page 4.) The Examiner does not allege and Oh does not teach or suggest "wherein the first light guide comprises a distal end having an exposed end surface that is configured to engage a portion of a body of the subject" and "wherein the second light guide comprises a distal end having an exposed end surface that is configured to engage a portion of the body of the subject," as recited in Claim 1. Moreover, the Examiner does not allege and Oh does not teach or suggest "wherein the first light guide is configured to deliver light from the at least one optical emitter ***directly into the body of the subject via the exposed end surface*** thereof" and "wherein the second light guide is configured to ***collect light directly from the body of the subject via the exposed end surface*** thereof and deliver collected light to the at least one

optical detector," as recited in Claim 1. Thus, Oh fails to rectify the deficiencies of Aceti with respect to independent Claim 1. As such, Claims 3, 4 and 11 are patentable and the rejections of Claims 3, 4 and 11 under §103 are overcome.

c) Claims 5, 6, 14 and 15

Claims 5, 6, 14 and 15 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Aceti in view of Uchida. Claims 5 and 6 depend from independent Claim 1, and Claims 14 and 15 depend from independent Claim 12. Independent Claims 1 and 12 are patentable over Aceti for at least the reasons discussed above. The secondary reference, Uchida, fails to rectify the deficiencies of Aceti with respect to independent Claims 1 and 12. Uchida is only cited for disclosing the use of filters. (Action, page 6.) The Examiner does not allege and Uchida does not teach or suggest "wherein the first light guide comprises a distal end having an exposed end surface that is configured to engage a portion of a body of the subject" and "wherein the second light guide comprises a distal end having an exposed end surface that is configured to engage a portion of the body of the subject," as recited in Claim 1. Moreover, the Examiner does not allege and Uchida does not teach or suggest "wherein the first light guide is configured to deliver light from the at least one optical emitter ***directly into the body of the subject via the exposed end surface*** thereof" and "wherein the second light guide is configured to ***collect light directly from the body of the subject via the exposed end surface*** thereof and deliver collected light to the at least one optical detector," as recited in Claim 1. In addition, the Examiner does not allege and Uchida does not teach or suggest a sensor module having a processor that is configured to process signals produced by an optical detector "to determine a plurality of physiological parameters, comprising two or more of the following: subject heart rate, respiration rate, blood flow, heart rate variability, and blood gas level," as recited in Claim 12. Thus, Uchida fails to rectify the deficiencies of Aceti with respect to independent Claims 1 and 12. As such, Claims 5, 6, 14 and 15 are patentable and the rejections of Claims 5, 6, 14 and 15 under §103 are overcome.

Claims 15 and 19 Are Separately Patentable

Claim 15 recites "wherein the processor utilizes at least one digital filter and at least one peak finding algorithm to process signals produced by the at least one optical detector to determine the plurality of physiological parameters." Aceti, Oh and Uchida are wholly silent

as to utilizing a digital filter and at least one peak finding algorithm. As such, Claim 15 is separately patentable.

Claim 19 recites a processor "configured to process signals produced by the at least one optical detector to determine ***all of the following***: subject heart rate, respiration rate, blood flow, heart rate variability, and blood gas level." Aceti, Oh and Uchida are wholly silent as to a processor configured to process signals by an optical detector to determine subject heart rate, respiration rate, blood flow, heart rate variability, ***and*** blood gas level. As such, Claim 19 is separately patentable.

Dependent Claims

As each of the dependent claims depends from a base claim that is believed to be in condition for allowance, Applicants do not believe that it is necessary to argue the allowability of each dependent claim individually. Applicants do not necessarily concur with the interpretation of these claims, or with the bases for rejection set forth in the Action. Applicants therefore reserve the right to address the patentability of these claims individually as necessary in the future.

Double Patenting Rejections Overcome

Claims 1-20 stand rejected on the ground of nonstatutory double patenting as being unpatentable over Claims 1-30 of U.S. Patent No. 8,788,002. Claims 1-20 stand rejected on the ground of nonstatutory double patenting as being unpatentable over Claims 1-42 of U.S. Patent No. 8,700,111. Claims 1-20 stand provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over Claims 1-20 of co-pending U.S. Patent Application No. 14/298,219. Claims 1-20 stand provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over Claims 1-21 of co-pending U.S. Patent Application No. 14/298,402. Claims 1-20 stand provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over Claims 1-42 of co-pending U.S. Patent Application No. 14/184,364. Claims 1-20 stand provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over Claims 1-20 of co-pending U.S. Patent Application No. 14/194,891.

In order to advance the present application to allowance, a Terminal Disclaimer is being filed concurrently to overcome the non-statutory obviousness-type double patenting

rejections based on U.S. Patent No. 8,788,002, U.S. Patent No. 8,700,111, co-pending U.S. Patent Application No. 14/298,219, co-pending U.S. Patent Application No. 14/298,402, co-pending U.S. Patent Application No. 14/184,364, and co-pending U.S. Patent Application No. 14/194,891. The filing of this Terminal Disclaimer shall not be construed as an admission that the claims are unpatentable under the judicially created doctrine of obviousness-type double patenting or are obvious under 35 USC §103.

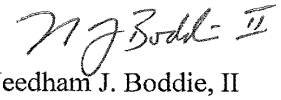
Supplemental Information Disclosure Statement

Applicants are concurrently submitting a Supplemental Information Disclosure Statement (IDS) for the Examiner's consideration. Return of the initialed IDS is respectfully requested.

CONCLUSION

In view of the above, it is respectfully submitted that this application is in condition for allowance, which action is respectfully requested.

Respectfully submitted,



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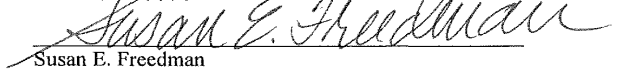
CERTIFICATION OF TRANSMISSION

I hereby certify that this correspondence is being transmitted via the Office electronic filing system in accordance with 37 C.F.R. § 1.6(a)(4) to the U.S. Patent and Trademark Office on **August 26, 2014**.



Susan E. Freedman

Attorney Docket No. 9653-7IPCT PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re: LeBoeuf et al. Confirmation No.: 9722
Application No.: 14/274,288 Examiner: Rodney Evan Fuller
Filing Date: May 9, 2014 Group Art Unit: 2852
For: LIGHT GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME

August 26, 2014

Mail Stop Amendment
Commissioner for Patents
Box 1450
Alexandria, VA 22313-1450

INFORMATION DISCLOSURE STATEMENT TRANSMITTAL

Sir:

Attached is an Information Disclosure Statement listing of documents, together with a copy of any listed foreign patent document and/or non-patent literature. A copy of any listed U.S. patent and/or U.S. patent application publication is not provided herewith in accordance with 37 C.F.R. § 1.98(a)(2)(ii).

☐ In accordance with **37 CFR 1.97(b)**, the information disclosure statement is being filed:

- ☐ (1) within three months of the filing date of a national application other than a continued prosecution application under §1.53(d);
- ☐ (2) within three months of the date of entry of the national stage as set forth in §1.491 in an international application;
- ☐ (3) before the mailing of a first Office Action on the merits; or
- ☐ (4) before the mailing of a first Office Action after the filing of a request for continued examination under §1.114.

☒ In accordance with **37 CFR 1.97(c)**, the information disclosure statement is being filed after the period specified in 37 CFR 1.97(b) above, but before the mailing date of any of a final action under §1.113, a notice of allowance under §1.311, or an action that otherwise closes prosecution in the application, and is accompanied by **one** of the following:

☐ (1) The statement specified under **37 CFR 1.97(e)**, as follows:

☐ Each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement; **or**

☐ No item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement; **or**

☒ (2) The fee set forth in §1.17(p);

☐ In accordance with **37 CFR 1.97(d)**, the information disclosure statement is being filed after the period specified in 37 CFR 1.97(c) above, but on or before payment of the issue fee, and is accompanied by **both** of the following:

☐ (1) The statement specified under **37 CFR 1.97(e)**, as follows:

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement; **or**

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement; **and**

☐ (2) The fee set forth in §1.17(p);

In accordance with **37 CFR 1.97(g)**, the information disclosure statement shall not be construed as a representation that a search has been made.

In accordance with **37 CFR 1.97(h)**, the information disclosure statement shall not be construed to be an admission that the information cited in the statement is, or is considered to be, material to patentability as defined in §1.56(b).

☒ The Director is hereby authorized to charge the fee specified in 37 C.F.R. § 1.17(p), and any fee deficiency or credit any overpayment, to Deposit Account No. 50-0220; or

☐ No fee is believed due. However, the Director is hereby authorized to charge any deficiency or credit any overpayment to Deposit Account No. 50-0220.

Respectfully submitted,

/N J Boddie II/

Needham J. Boddie, II
Registration No. 40,519
Attorney for Applicant

Customer Number 20792
Myers Bigel Sibley & Sajovec, P.A.
P.O. Box 37428, Raleigh, NC 27627
919-854-1400
919-854-1401 (Fax)

CERTIFICATION OF TRANSMISSION

I hereby certify that this correspondence is being transmitted via the Office electronic filing system in accordance with 37 CFR § 1.6(a)(4) to the U.S. Patent and Trademark Office on August 26, 2014.

/Susan E. Freedman/

Susan E. Freedman

Doc Code: DIST.E.FILE **Document Description: Electronic Terminal Disclaimer - Filed**	PTO/SB/25 PTO/SB/26 U.S. Patent and Trademark Office Department of Commerce

Electronic Petition Request	**TERMINAL DISCLAIMER TO OBVIATE A PROVISIONAL DOUBLE PATENTING REJECTION OVER A PENDING "REFERENCE" APPLICATION AND TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION OVER A "PRIOR" PATENT**
Application Number	14274288
Filing Date	09-May-2014
First Named Inventor	Steven LeBoeuf
Attorney Docket Number	9653-7IPCT
Title of Invention	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME

☒ Filing of terminal disclaimer does not obviate requirement for response under 37 CFR 1.111 to outstanding Office Action

☒ This electronic Terminal Disclaimer is not being used for a Joint Research Agreement.

Owner	Percent Interest
Valencell, Inc.	100 %

The owner(s) of percent interest listed above in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of any patent granted on pending reference Application Number(s)

14194891 filed on 03/03/2014

14184364 filed on 02/19/2014

14298402 filed on 06/06/2014

14298219 filed on 06/06/2014

as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and any patent granted on the reference application are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of any patent granted on the instant application that would extend to the expiration date of the full statutory term of any patent granted on said reference application, "as the term of any patent granted on said reference application may be shortened by any terminal disclaimer filed prior to the grant of any patent on the pending reference application," in the event that any such patent granted on the pending reference application: expires for failure to pay a maintenance fee, is held unenforceable, is found invalid by a court of competent jurisdiction, is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321, has all claims canceled by a reexamination certificate, is reissued, or is in any manner terminated prior to the expiration of its full statutory term as shortened by any terminal disclaimer filed prior to its grant.

The owner(s) with percent interest listed above in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term of prior patent number(s)

8700111

8788002

as the term of said prior patent is presently shortened by any terminal disclaimer. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and the prior patent are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of the term of any patent granted on the instant application that would extend to the expiration date of the full statutory term of the prior patent, "as the term of said prior patent is presently shortened by any terminal disclaimer," in the event that said prior patent later:
- expires for failure to pay a maintenance fee;
- is held unenforceable;
- is found invalid by a court of competent jurisdiction;
- is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321;
- has all claims canceled by a reexamination certificate;
- is reissued; or
- is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.

◉ Terminal disclaimer fee under 37 CFR 1.20(d) is included with Electronic Terminal Disclaimer request.

○ I certify, in accordance with 37 CFR 1.4(d)(4), that the terminal disclaimer fee under 37 CFR 1.20(d) required for this terminal disclaimer has already been paid in the above-identified application.

Applicants claims the following fee status:

○ Small Entity

○ Micro Entity

◉ Regular Undiscounted

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

THIS PORTION MUST BE COMPLETED BY THE SIGNATORY OR SIGNATORIES

I certify, in accordance with 37 CFR 1.4(d)(4) that I am:

◉ An attorney or agent registered to practice before the Patent and Trademark Office who is of record in this application

Registration Number 40519

○ A sole inventor

○ A joint inventor; I certify that I am authorized to sign this submission on behalf of all of the inventors as evidenced by the power of attorney in the application

○ A joint inventor; all of whom are signing this request

Signature	/Needham J. Boddie, II/
Name	Needham J. Boddie, II

*Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner).
Form PTO/SB/96 may be used for making this certification. See MPEP § 324.

Electronic Patent Application Fee Transmittal

Application Number:	14274288
Filing Date:	09-May-2014
Title of Invention:	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME
First Named Inventor/Applicant Name:	Steven Francis LeBoeuf
Filer:	Needham J. Boddie
Attorney Docket Number:	9653-7IPCT

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Statutory or Terminal Disclaimer	1814	1	160	160
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
		Total in USD ($)		**160**

Doc Code: DISQ.E.FILE
Document Description: Electronic Terminal Disclaimer – Approved

Application No.: 14274288

Filing Date: 09-May-2014

Applicant/Patent under Reexamination: LeBoeuf et al.

Electronic Terminal Disclaimer filed on August 26, 2014

☒ APPROVED

This patent is subject to a terminal disclaimer

☐ DISAPPROVED

Approved/Disapproved by: Electronic Terminal Disclaimer automatically approved by EFS-Web

U.S. Patent and Trademark Office

Electronic Acknowledgement Receipt

EFS ID:	19967669
Application Number:	14274288
International Application Number:	
Confirmation Number:	9722
Title of Invention:	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME
First Named Inventor/Applicant Name:	Steven Francis LeBoeuf
Customer Number:	20792
Filer:	Needham J. Boddie
Filer Authorized By:	
Attorney Docket Number:	9653-7IPCT
Receipt Date:	26-AUG-2014
Filing Date:	09-MAY-2014
Time Stamp:	14:39:12
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$160
RAM confirmation Number	892
Deposit Account	500220
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Electronic Terminal Disclaimer-Filed	eTerminal-Disclaimer.pdf	40551 8c798a63c263e0634c064c598442221c2491dc0c	no	3
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30383 5d4b33868c6e9410d06732ee7b4ac043efe180b1	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	70934		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 14/274,288	Filing Date 05/09/2014	☐ To be Mailed

ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)		
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT	08/26/2014	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X $80 =	0
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X $420 =	0
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	**0**

AMENDMENT		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
	Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/Ruby Johnson/

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
14/274,288	05/09/2014	Steven Francis LeBoeuf	9653-7IPCT

CONFIRMATION NO. 9722

20792
MYERS BIGEL SIBLEY & SAJOVEC
PO BOX 37428
RALEIGH, NC 27627

PUBLICATION NOTICE

OC000000070552911

Title:LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME

Publication No.US-2014-0249381-A1
Publication Date:09/04/2014

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/274,288	05/09/2014	Steven Francis LeBoeuf	9653-7IPCT	9722

20792 7590 10/27/2014

MYERS BIGEL SIBLEY & SAJOVEC
PO BOX 37428
RALEIGH, NC 27627

EXAMINER	
FULLER, RODNEY EVAN	
ART UNIT	PAPER NUMBER
2852	

MAIL DATE	DELIVERY MODE
10/27/2014	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 14/274,288	Applicant(s) LEBOEUF ET AL.	
	Examiner RODNEY FULLER	Art Unit 2852	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *08/26/2014*.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *1-20* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☒ Claim(s) *1-11 and 20* is/are allowed.

7)☒ Claim(s) *12-19* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *05/09/2014* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)

2) ☒ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date *8/26/2014*.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

4) ☐ Other: _____.

DETAILED ACTION

1. The present application is being examined under the pre-AIA first to invent provisions.

Terminal Disclaimer

2. The terminal disclaimers filed on 08/26/2014 disclaiming the terminal portion of any patent granted on this application which would extend beyond the expiration date of US Patent Nos. 8,700,111 and 8,788,002 and any patent granted on Application Numbers 14/194,891, 14/184,364, 14/298,402 and 14/298,219 have been reviewed and is accepted. The terminal disclaimers have been recorded.

Remarks

3. In response to applicant's Amendment, dated 08/26/2014, the examiner has considered applicant's arguments in light of the amended claims withdraws the rejections for claims 1-10 and 20.

4. Regarding the rejection of claims 12-19, the applicant makes the argument that "neither Aceti nor Oh teach or suggest a sensor module having a processor that is configured to process signals produced by an optical detector to determine a plurality of physiological parameters, comprising two or more of the following: subject heart rate, respiration rate, blood flow, heart rate variability and blood gas level". The examiner maintains Aceti does disclose a processor (i.e., ref.# 244: circuitry to process information; see column 6, lines 5-16) and at least determines heart rate and blood gas level (See abstract). Thus, the examiner has considered applicant's arguments in light of the amended claims and maintains the rejection of claims 12-19

Claim Rejections - 35 USC § 103

5. The following is a quotation of pre-AIA 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

6. Claims 12, 13 and 16-19 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Aceti (US 7,107,088) in view of Oh, et al. (US 8,055,319).

Regarding claim 12, Aceti discloses all the structure set forth in the claims except (Claim 12) "a motion sensor supported by the housing, wherein the motion sensor is configured to sense motion information from the subject; and a processor supported by the housing, wherein the processor is configured to remove motion artifacts from signals produced by the at least one optical detector in response to signals produced by the motion sensor". However, the use of a motion sensor and associated processor to determine and compensate for noise produced by motion of a user was well known in the art at the time the invention was made as evident from the teaching of Oh (See column 2, lines 60-67). Thus, it would have been obvious to one of ordinary skill in the art at the time the invention was made to modify Aceti by including a motion sensor and associated processor to remove noise due to motion and improve the accuracy of the measurements.

Regarding claim 13, Aceti discloses “wherein the housing is configured to be integrated within an audio headset, a wrist strap, a wrist watch, an ankle bracelet, or an armband.” (column 1, lines 35-37: finger, ear, foot)

Regarding claim 16, Aceti discloses “wherein at least one of the first and second light guides comprises elastomeric light transmissive material.” (Fig. 2, ref.# 224a, 224b; column 4, lines 31-35))

Regarding claim 17, Aceti discloses "wherein at least one of the first and second light guides comprises substantially rigid light transmissive material.” (Fig. 2, ref.# 232, 242: fibers, i.e., rigid)

Regarding claim 18, Aceti discloses "wherein the at least one optical emitter (Fig. 2, ref.# 228) comprises optical coupling material (Fig. 2, ref.# 232, 236), and wherein the first light guide (Fig. 2, ref.# 224a) is in optical communication with the at least one optical emitter via the optical coupling material.”

Regarding claim 19, Aceti discloses “wherein the at least one optical detector (Fig. 2, ref.# 238) comprises optical coupling material (Fig. 2, ref.# 242), and wherein the second light guide (Fig. 2, ref.# 224b) is in optical communication with the at least one optical detector via the optical coupling material.”

7. Claims 14 and 15 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Aceti (US 7,107,088) in view of Uchida, et al. (US 6,078,829).

Aceti discloses all the structure set forth in the claims except (Claim 14) “wherein the first light guide comprises optical dye that is configured to filter one or more

wavelengths of light guided by first light guide" and (Claim 15) "wherein the second light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by second light guide." However, the use of filters (i.e., optical dyes to filter wavelengths) with optical systems that measure biological information (i.e., reflectance from blood) was well known in the invention was made as evident from the teaching of Uchida (See columns 5-6). Thus, it would have been obvious to one of ordinary skill in the art at the time the invention was made to modify Aceti by including optical dye (i.e., filters) with the light guides in order to selectively choose wavelength (i.e., specific bands) in order to accurately determine information such as blood sugar, oxygen content, etc.

Allowable Subject Matter

8. Claims 1-11 and 20 are allowed.

Conclusion

9. **THIS ACTION IS MADE FINAL.** Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of

the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

10. Any inquiry concerning this communication or earlier communications from the examiner should be directed to RODNEY FULLER whose telephone number is (571)272-2118. The examiner can normally be reached on 8:00am - 4:30pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Clayton Laballe can be reached on 571-272-1594. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/RODNEY FULLER/
Primary Examiner, Art Unit 2852

October 24, 2014

In the Specification:

Please amend the paragraph beginning on page 5, line 3 of the specification as follows:

-- In some embodiments, an earbud includes at least one lens in optical communication with the light transmissive material. Each lens may be configured to focus light from the optical emitter onto one or more predetermined locations in the ear of a subject and/or to focus collected external light onto the optical detector. --

Please amend the paragraph beginning on page 16, line 27 of the specification as follows:

-- Fig. 6 is a side section view of a light-guiding earbud for a headset, according to some embodiments of the present invention.[[.]] --

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (use as many sheets as necessary) Sheet 1 of 1	Complete if Known	
	Application Number	14/274,288
	Filing Date	05-09-2014
	First Named Inventor	Steven Francis LeBoeuf
	Art Unit	2852
	Examiner Name	Rodney Evan Fuller
	Attorney Docket Number	9653-7IPCT

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.	Document Number Number-Kind Code (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
	1.	US- 2012/0179011 A1	07-12-2012	Moon et al.	
	2.	US- 2004/0225207 A1	11-11-2004	Bae et al.	
	3.	US- 6,783,501 B2	08-31-2004	Takahashi et al.	
		US-			
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FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.	Foreign Patent Document Country Code, Number, Kind Code (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T
	4.	WO 2013/038296 A1	03-21-2013	KONINKLIJKE PHILIPS ELECTRONICS N.V.		
	5.	EP 2 077 091 A2	07-08-2009	PERCEPTION DIGITAL LIMITED		

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published	T

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /RF/

Examiner Signature	/Rodney Fuller/	Date Considered	10/24/2014

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14274288	LEBOEUF ET AL.
	Examiner	Art Unit
	RODNEY FULLER	2852

CPC- SEARCHED		
Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
600	310	10/24/2014	/RF/

SEARCH NOTES		
Search Notes	Date	Examiner
East text search history printout	10/24/2014	/RF/
600/310, 322, 323, 324 (w/ text search)	10/24/2014	/RF/
CPC w/ text search	10/24/2014	/RF/

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

	/RODNEY FULLER/ Primary Examiner.Art Unit 2852

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	4	(("20100217103") or ("20040225207") or ("20040054291") or ("20040034293")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/10/24 15:13
S2	1	S1 and concha	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:15
S3	39	("20050228299" | "20090287067" | "20100298653" | "6078829" | "20120197093" | "5086229" | "6080110" | "6371925" | "6859658" | "20080177162" | "20090105556" | "20100168531" | "20080076972" | "20090030350" | "5596987" | "6783501" | "20090054752" | "6358216" | "7107088" | "20060009685" | "20090270698" | "20110105869" | "20130131519" | "7209775" | "8512242" | "8055319" | "20050043600" | "20050177034" | "20050209516" | "20080096726" | "20080165017" | "20090054752" | "6808473" | "8251903" | "20040034293" | "20120179011" | "20040054291" | "20100217103" | "8055319" | "20030109030" | "20040225207").PN.	US-PGPUB; USPAT; USOCR	OR	ON	2014/10/24 15:32
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S9	2	(("8700111") or ("8788002")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/10/24 15:34
S10	33	("20040034293" | "20040054291" | "20050043600" | "20050177034" | "20050209516" | "20050228299" | "20060009685" | "20080076972" | "20080096726" | "20080165017" | "20080177162" | "20090030350" | "20090054752" | "20090105556" | "20090270698" | "20090287067" | "20100168531" | "20100217103" | "20100298653" | "20110105869" | "20120197093" | "20130131519" | "5086229" | "5596987" | "6078829" | "6080110" | "6371925" | "6808473" | "6859658" | "7209775" | "8055319" | "8251903" | "8512242").PN. OR ("8788002").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2014/10/24 15:34
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S12	45	S1 or S2 or S3 or S4 or S5 or S6 or S7 or S8 or S9 or S10 or S11	US-PGPUB; USPAT; USOCR	OR	ON	2014/10/24 15:35
S13	4686	((600/310) or (600/322) or (600/323) or (600/324)).CCLS.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/10/24 15:38
S14	1505	S13 and (ear or earbud)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:39
S15	20	S14 and (concha)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:39
S16	1505	S14 and ear	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:40
S17	106	S16 and concentric	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:40
S18	280	S13 and concentric	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:40
S19	14	S18 and cladding	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:40
S20	27	S16 and cladding	US-PGPUB; USPAT; USOCR;	OR	ON	2014/10/24 15:41

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S21	20	S20 and adhesive	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:41
S22	339	(light or emitter) and (sensor or detector) and ear and concha	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:43
S23	631696	ear or earbud	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:45
S24	3236	S23 and concha	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:45
S25	502	S24 and (antitragus or anti-tragus or (anti adj tragus))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:45
S26	165	S25 and (emitter or light)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:45
S27	79	S26 and (detector or sensor)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 15:45
S28	25	S27 and (window or aperture)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/10/24 16:02

10/24/2014 4:45:37 PM
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Attorney Docket No.: 9653-7IPCT **PATENT**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re: LeBoeuf et al. Confirmation No.: 9722

Serial No.: 14/274,288 Group Art Unit: 2852

Filed: May 9, 2014 Examiner: Rodney Evan Fuller

For: **LIGHT GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME**

Date: October 28, 2014

Mail Stop AF
Commissioner for Patents
P. O. Box 1450
Alexandria, VA 22313-1450

RESPONSE TO FINAL OFFICE ACTION OF OCTOBER 27, 2014

Applicants provide the present Response to address the issues raised in the Final Office Action (the "Action") mailed October 27, 2014. Applicants provide the present Response pursuant to the rules stated in revised 37 C.F.R. 1.121 that became effective on July 30, 2003.

It is not believed that an extension of time and/or additional fee(s)-including fees for net addition of claims-are required, beyond those that may otherwise be provided for in documents accompanying this paper. In the event, however, that an extension of time is necessary to allow consideration of this paper, such an extension is hereby petitioned under 37 C.F.R. §1.136(a). Any additional fees believed to be due in connection with this paper may be charged to our Deposit Account No. 50-0220.

Amendments to the claims begin on Page 2 of this paper.

Remarks begin on Page 5 of this paper.

This listing of claims replaces all prior versions in the application.

Listing of Claims:

1. (Previously Presented) A sensor module for detecting and/or measuring physiological information from a subject, the sensor module comprising:

a housing;

at least one optical emitter supported by the housing;

at least one optical detector supported by the housing;

a first light guide supported by the housing, wherein the first light guide is in optical communication with the at least one optical emitter, wherein the first light guide comprises a distal end having an exposed end surface that is configured to engage a portion of a body of the subject, and wherein the first light guide is configured to deliver light from the at least one optical emitter directly into the body of the subject via the exposed end surface thereof; and

a second light guide supported by the housing, wherein the second light guide is in optical communication with the at least one optical detector, wherein the second light guide comprises a distal end having an exposed end surface that is configured to engage a portion of the body of the subject, and wherein the second light guide is configured to collect light directly from the body of the subject via the exposed end surface thereof and deliver collected light to the at least one optical detector.

2. (Original) The sensor module of Claim 1, wherein the housing is configured to be integrated within an audio headset, a wrist strap, a wrist watch, an ankle bracelet, or an armband.

3. (Original) The sensor module of Claim 1, further comprising at least one motion sensor supported by the housing, wherein the at least one motion sensor is configured to sense motion information from the subject.

4. (Original) The sensor module of Claim 3, further comprising at least one processor supported by the housing, wherein the at least one processor is configured to

remove motion artifacts from signals produced by the at least one optical detector in response to signals produced by the at least one motion sensor.

5. (Original) The sensor module of Claim 1, wherein the first light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by first light guide.

6. (Original) The sensor module of Claim 1, wherein the second light guide comprises optical dye that is configured to filter one or more wavelengths of light guided by second light guide.

7. (Original) The sensor module of Claim 1, wherein at least one of the first and second light guides comprises elastomeric light transmissive material.

8. (Original) The sensor module of Claim 1, wherein at least one of the first and second light guides comprises substantially rigid light transmissive material.

9. (Original) The sensor module of Claim 1, wherein the at least one optical emitter comprises optical coupling material, and wherein the first light guide is in optical communication with the at least one optical emitter via the optical coupling material.

10. (Original) The sensor module of Claim 1, wherein the at least one optical detector comprises optical coupling material, and wherein the second light guide is in optical communication with the at least one optical detector via the optical coupling material.

11. (Original) The sensor module of Claim 3, further comprising at least one processor supported by the housing, wherein the at least one processor is configured to process signals produced by the at least one optical detector and signals produced by the at least one motion sensor to determine subject heart rate and respiration rate.

12-19. (Cancelled)

20. (Previously Presented) A sensor module for detecting and/or measuring physiological information from a subject, the sensor module, comprising:

a housing;

an optical emitter supported by the housing;

an optical detector supported by the housing;

a first light guide supported by the housing, wherein the first light guide is in optical communication with the optical emitter, wherein the first light guide comprises a distal free end having an exposed end surface that is configured to engage a portion of a body of the subject, and wherein the first light guide is configured to deliver light from the optical emitter directly into the body of the subject via the exposed end surface thereof; and

a second light guide supported by the housing, wherein the second light guide is in optical communication with the optical detector, wherein the second light guide comprises a distal free end having an exposed end surface that is configured to engage a portion of the body of the subject, and wherein the second light guide is configured to collect light directly from the body of the subject via the exposed end surface thereof and deliver collected light to the optical detector,

wherein the distal free ends of the first and second light guides are in adjacent, spaced-apart relationship.

REMARKS

After the above amendments, Claims 1-11 and 20 are pending.

Claims 1-11 and 20 are allowed.

Claims 12, 13 and 16-19 stand rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 7,107,088 to Aceti ("Aceti") in view of U.S. Patent No. 8,055,319 to Oh et al. ("Oh").

Claims 14 and 15 stand rejected under 35 U.S.C. §103(a) as being unpatentable over Aceti in view of U.S. Patent No. 6,078,829 to Uchida et al. ("Uchida").

Applicants have cancelled Claims 12-19 without prejudice or disclaimer.

In view of the above, it is respectfully submitted that this application is in condition for allowance, which action is respectfully requested.

Respectfully submitted,

NJ Boddie II

Needham J. Boddie, II
Attorney for Applicants
Registration No. 40,519

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Facsimile: (919) 854-1401
Doc. No. 1598091

CERTIFICATION OF TRANSMISSION

I hereby certify that this correspondence is being transmitted via the Office electronic filing system in accordance with 37 C.F.R. § 1.6(a)(4) to the U.S. Patent and Trademark Office on **October 28, 2014**.

Candi L. Riggs

Candi L. Riggs

Electronic Acknowledgement Receipt

EFS ID:	20530715
Application Number:	14274288
International Application Number:	
Confirmation Number:	9722
Title of Invention:	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME
First Named Inventor/Applicant Name:	Steven Francis LeBoeuf
Customer Number:	20792
Filer:	Needham J. Boddie/Candi Riggs
Filer Authorized By:	Needham J. Boddie
Attorney Docket Number:	9653-7IPCT
Receipt Date:	28-OCT-2014
Filing Date:	09-MAY-2014
Time Stamp:	07:53:28
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		9653-7IPCT_Response.pdf	411693 520d391d11399dbcae790361a4f1cb1d5bfa6d93	yes	5

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Response After Final Action	1	1
	Claims	2	4
	Applicant Arguments/Remarks Made in an Amendment	5	5
Warnings:			
Information:			
	Total Files Size (in bytes):	411693	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 14/274,288	Filing Date 05/09/2014	☐ To be Mailed

ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

	(Column 1)	(Column 2)		
FOR	NUMBER FILED	NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

	(Column 1)		(Column 2)	(Column 3)		
AMENDMENT	**10/28/2014**	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
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	Independent (37 CFR 1.16(h))	* 2	Minus	***3	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

	(Column 1)		(Column 2)	(Column 3)		
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
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	Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
	☐ Application Size Fee (37 CFR 1.16(s))						
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
						TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/TERRANCE LAWRENCE/

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NOTICE OF ALLOWANCE AND FEE(S) DUE

20792 7590 11/12/2014

MYERS BIGEL SIBLEY & SAJOVEC
PO BOX 37428
RALEIGH, NC 27627

EXAMINER
FULLER, RODNEY EVAN

ART UNIT	PAPER NUMBER
2852	

DATE MAILED: 11/12/2014

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/274,288	05/09/2014	Steven Francis LeBoeuf	9653-7IPCT	9722

TITLE OF INVENTION: LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$960	$0	$0	$960	02/12/2015

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

20792 7590 11/12/2014
MYERS BIGEL SIBLEY & SAJOVEC
PO BOX 37428
RALEIGH, NC 27627

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/274,288	05/09/2014	Steven Francis LeBoeuf	9653-7IPCT	9722

TITLE OF INVENTION: LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$960	$0	$0	$960	02/12/2015

EXAMINER	ART UNIT	CLASS-SUBCLASS
FULLER, RODNEY EVAN	2852	600-310000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
- ❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
- ❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:
- ❑ Issue Fee
- ❑ Publication Fee (No small entity discount permitted)
- ❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ❑ A check is enclosed.
- ❑ Payment by credit card. Form PTO-2038 is attached.
- ❑ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ❑ Applicant certifying micro entity status. See 37 CFR 1.29 — NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
- ❑ Applicant asserting small entity status. See 37 CFR 1.27 — NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
- ❑ Applicant changing to regular undiscounted fee status. — NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/274,288	05/09/2014	Steven Francis LeBoeuf	9653-7IPCT	9722

20792 7590 11/12/2014

MYERS BIGEL SIBLEY & SAJOVEC
PO BOX 37428
RALEIGH, NC 27627

EXAMINER	
FULLER, RODNEY EVAN	
ART UNIT	PAPER NUMBER
2852	

DATE MAILED: 11/12/2014

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 14/274,288	Applicant(s) LEBOEUF ET AL.	
	Examiner RODNEY FULLER	Art Unit 2852	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *applicant's Amendment, dated 10/28/2014*.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on_____.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *1-11 and 20*. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov .
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:
   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/RODNEY FULLER/
Primary Examiner, Art Unit 2852

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14274288	LEBOEUF ET AL.
	Examiner	Art Unit
	RODNEY FULLER	2852

CPC- SEARCHED		
Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
600	310	11/4/2014	/RF/

SEARCH NOTES		
Search Notes	Date	Examiner
East text search history printout	11/4/2014	/RF/
600/310, 322, 323, 324 (w/ text search)	11/4/2014	/RF/
CPC w/ text search	11/4/2014	/RF/

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
	Interference search history printout	11/4/2014	/RF/

	/RODNEY FULLER/ Primary Examiner.Art Unit 2852

Receipt date: 10/28/2014 14274288 - GAU: 2852

OK TO ENTER: /RF/

Attorney Docket No.: 9653-7IPCT **PATENT**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re: LeBoeuf et al. Confirmation No.: 9722

Serial No.: 14/274,288 Group Art Unit: 2852

Filed: May 9, 2014 Examiner: Rodney Evan Fuller

For: **LIGHT GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME**

Date: October 28, 2014

Mail Stop AF
Commissioner for Patents
P. O. Box 1450
Alexandria, VA 22313-1450

RESPONSE TO FINAL OFFICE ACTION OF OCTOBER 27, 2014

Applicants provide the present Response to address the issues raised in the Final Office Action (the "Action") mailed October 27, 2014. Applicants provide the present Response pursuant to the rules stated in revised 37 C.F.R. 1.121 that became effective on July 30, 2003.

It is not believed that an extension of time and/or additional fee(s)-including fees for net addition of claims-are required, beyond those that may otherwise be provided for in documents accompanying this paper. In the event, however, that an extension of time is necessary to allow consideration of this paper, such an extension is hereby petitioned under 37 C.F.R. §1.136(a). Any additional fees believed to be due in connection with this paper may be charged to our Deposit Account No. 50-0220.

Amendments to the claims begin on Page 2 of this paper.

Remarks begin on Page 5 of this paper.

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14274288	LEBOEUF ET AL.
	Examiner	**Art Unit**
	RODNEY FULLER	2852

CPC						
Symbol					**Type**	**Version**
A61B		5	/	6817	F	2013-01-01
A61B		5	/	0077	I	2013-01-01
A61B		5	/	6815	I	2013-01-01
H04R		1	/	1091	I	2013-01-01
A61B		5	/	6835	I	2013-01-01
A61B		5	/	0059	I	2013-01-01
A61B		5	/	0082	I	2013-01-01
A61B		5	/	0205	I	2013-01-01
A61B		5	/	11	I	2013-01-01
A61B		5	/	6803	I	2013-01-01
A61B		5	/	681	I	2013-01-01
A61B		5	/	0084	I	2013-01-01
A61B		5	/	721	I	2013-01-01
A61B		5	/	7225	I	2013-01-01
A61B		5	/	02427	A	2013-01-01
A61B		5	/	0816	A	2013-01-01

CPC Combination Sets							
Symbol					**Type**	**Set**	**Ranking**	**Version**
			/					
			/					

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	12	
/RODNEY FULLER/ Primary Examiner.Art Unit 2852	11/04/2014	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office — Part of Paper No. 20141104

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14274288	LEBOEUF ET AL.
	Examiner	**Art Unit**
	RODNEY FULLER	2852

US ORIGINAL CLASSIFICATION		INTERNATIONAL CLASSIFICATION										
CLASS	SUBCLASS	CLAIMED					NON-CLAIMED					
600	310	A	6	1	B	5 / 00 (2006.01.01)						
CROSS REFERENCE(S)												
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)											

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	12	
/RODNEY FULLER/ Primary Examiner.Art Unit 2852	11/04/2014	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office

Part of Paper No. 20141104

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	14274288	LEBOEUF ET AL.
	Examiner	**Art Unit**
	RODNEY FULLER	2852

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☒ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	-	17												
2	2	-	18												
3	3	-	19												
4	4	12	20												
6	5														
7	6														
8	7														
9	8														
10	9														
11	10														
5	11														
-	12														
-	13														
-	14														
-	15														
-	16														

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	12	
/RODNEY FULLER/ Primary Examiner.Art Unit 2852	11/04/2014	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1

U.S. Patent and Trademark Office Part of Paper No. 20141104

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	39	("20090287067" | "20100298653" | "6078829" | "20060009685" | "20120197093" | "5086229" | "6371925" | "6859658" | "20050209516" | "20080177162" | "20090105556" | "20100168531" | "6080110" | "20080076972" | "20090030350" | "5596987" | "6358216" | "7107088" | "6783501" | "20090270698" | "20110105869" | "20130131519" | "7209775" | "8512242" | "20040034293" | "20050043600" | "20050177034" | "20050228299" | "20080096726" | "20090054752" | "6808473" | "8251903" | "20040054291" | "20100217103" | "20080162017" | "8055319" | "20030109030" | "20040225207" | "20120179011").PN.	US-PGPUB; USPAT; USOCR	OR	ON	2014/11/04 08:47
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L6	2	(("8700111") or ("8788002")).PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/11/04 08:48
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L9	44	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8	US-PGPUB; USPAT; USOCR	OR	ON	2014/11/04 08:49
L10	4691	((600/310) or (600/322) or (600/323) or (600/324)).CCLS.	US-PGPUB; USPAT;	OR	OFF	2014/11/04 08:52

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L11	1455	10 and housing	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/04 08:52
L12	730	11 and ((light adj guide) or light-guide or lightguide or fiber or waveguide or wave-guide or (wave adj guide))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/04 08:53
L13	14	12 and (end adj surface)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/04 08:53
L14	0	9 and (direclty with collect)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/04 08:55
L15	0	9 and (directly with collect)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/04 08:55
L16	2	9 and (exposed with (fiber or guide))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/04 08:56
L17	27983	(emitter or light) with (detector or sensor) with housing	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/04 08:56
L18	490	10 and 17	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/04 08:56
L19	1	18 and (deliver with directly)	US-PGPUB; USPAT; USOCR; FPRS;	OR	ON	2014/11/04 08:57

			EPO; JPO; DERWENT; IBM_TDB			
L20	47	18 and (body with directly)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2014/11/04 08:57
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L23	2	("2013/0131519").URPN.	USPAT	OR	ON	2014/11/04 09:00
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L27	7	("2010/0217103").URPN.	USPAT	OR	ON	2014/11/04 09:01
L28	21	("2009/0287067").URPN.	USPAT	OR	ON	2014/11/04 09:01
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L30	18	("2005/0209516").URPN.	USPAT	OR	ON	2014/11/04 09:01
L31	97	("2005/0043600").URPN.	USPAT	OR	ON	2014/11/04 09:01
L32	170	23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31	USPAT	OR	ON	2014/11/04 09:02

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L33	0	(physiological and housing and (emitter or light) and (detector or sensor) and ((light adj guide) or light-guide or lightguide or fiber or (wave adj guide) or waveguide or wave-guide) and exposed and end and directly).clm.	USPAT; UPAD	OR	ON	2014/11/04 09:07

11/4/2014 9:07:58 AM
C:\Users\rfuller\Documents\EAST\Workspaces\rodney9.wsp

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

20792 7590 11/12/2014
MYERS BIGEL SIBLEY & SAJOVEC
PO BOX 37428
RALEIGH, NC 27627

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/274,288	05/09/2014	Steven Francis LeBoeuf	9653-7IPCT	9722

TITLE OF INVENTION: LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	$960	$0	$0	$960	02/12/2015

EXAMINER	ART UNIT	CLASS-SUBCLASS
FULLER, RODNEY EVAN	2852	600-310000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Myers Bigel Sibley & Sajovec
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Valencell, Inc.
(B) RESIDENCE: (CITY and STATE OR COUNTRY): Raleigh, NC

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
☒ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
☐ A check is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☒ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number 50-0220 (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
☐ Applicant certifying micro entity status. See 37 CFR 1.29
NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
☐ Applicant asserting small entity status. See 37 CFR 1.27
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
☐ Applicant changing to regular undiscounted fee status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature NJBoddie II Date 12/2/2014
Typed or printed name Needham J. Boddie, II Registration No. 40,519

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Electronic Patent Application Fee Transmittal

Application Number:	14274288
Filing Date:	09-May-2014
Title of Invention:	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME
First Named Inventor/Applicant Name:	Steven Francis LeBoeuf
Filer:	Needham J. Boddie/Candi Riggs
Attorney Docket Number:	9653-7IPCT

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl Issue Fee	1501	1	960	960
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
		Total in USD ($)		**960**

Electronic Acknowledgement Receipt

EFS ID:	20841130
Application Number:	14274288
International Application Number:	
Confirmation Number:	9722
Title of Invention:	LIGHT-GUIDING DEVICES AND MONITORING DEVICES INCORPORATING SAME
First Named Inventor/Applicant Name:	Steven Francis LeBoeuf
Customer Number:	20792
Filer:	Needham J. Boddie/Candi Riggs
Filer Authorized By:	Needham J. Boddie
Attorney Docket Number:	9653-7IPCT
Receipt Date:	02-DEC-2014
Filing Date:	09-MAY-2014
Time Stamp:	14:34:29
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	$960
RAM confirmation Number	780
Deposit Account	500220
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Issue Fee Payment (PTO-85B)	9653-7IPCT_FeesTransmittal.pdf	140709 92699c72995ba3792639dd74e0d1141737138bbd	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30642 7086700d863e1aa82bd046942bd3299180ce0be9	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	171351		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/274,288	01/06/2015	8929965	9653-7IPCT	9722

20792 7590 12/17/2014

MYERS BIGEL SIBLEY & SAJOVEC
PO BOX 37428
RALEIGH, NC 27627

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Steven Francis LeBoeuf, Raleigh, NC;
Valencell, Inc., Raleigh, NC, Assignee (with 37 CFR 1.172 Interest);
Jesse Berkley Tucker, Knightdale, NC;
Michael Edward Aumer, Raleigh, NC;
Steven Matthew Just, Cary, NC;