US 20180192898A1

(19) United States
(12) Patent Application Publication
Zhang et al.
(10) Pub. No.: US 2018/0192898 A1
(43) Pub. Date: Jul. 12, 2018

(54) NOVEL OPTICAL INTERFEROMETRIC SCANNING DETECTOR FOR CARDIOVASCULAR FUNCTION MONITORING

(71) Applicants: **Jin Zhang**, Ellicott City, MD (US); **Shan Zhong**, Clarksville, MD (US); **Wei Chen**, Ellicott City, MD (US); **Zhonghua Zhu**, Clarksville, MD (US); **Lei Wu**, Pleasanton, CA (US)

(72) Inventors: **Jin Zhang**, Ellicott City, MD (US); **Shan Zhong**, Clarksville, MD (US); **Wei Chen**, Ellicott City, MD (US); **Zhonghua Zhu**, Clarksville, MD (US); **Lei Wu**, Pleasanton, CA (US)

(73) Assignee: **OmniSensing Photonics, LLC**, Columbia, MD (US)

(21) Appl. No.: **15/403,184**

(22) Filed: **Jan. 11, 2017**

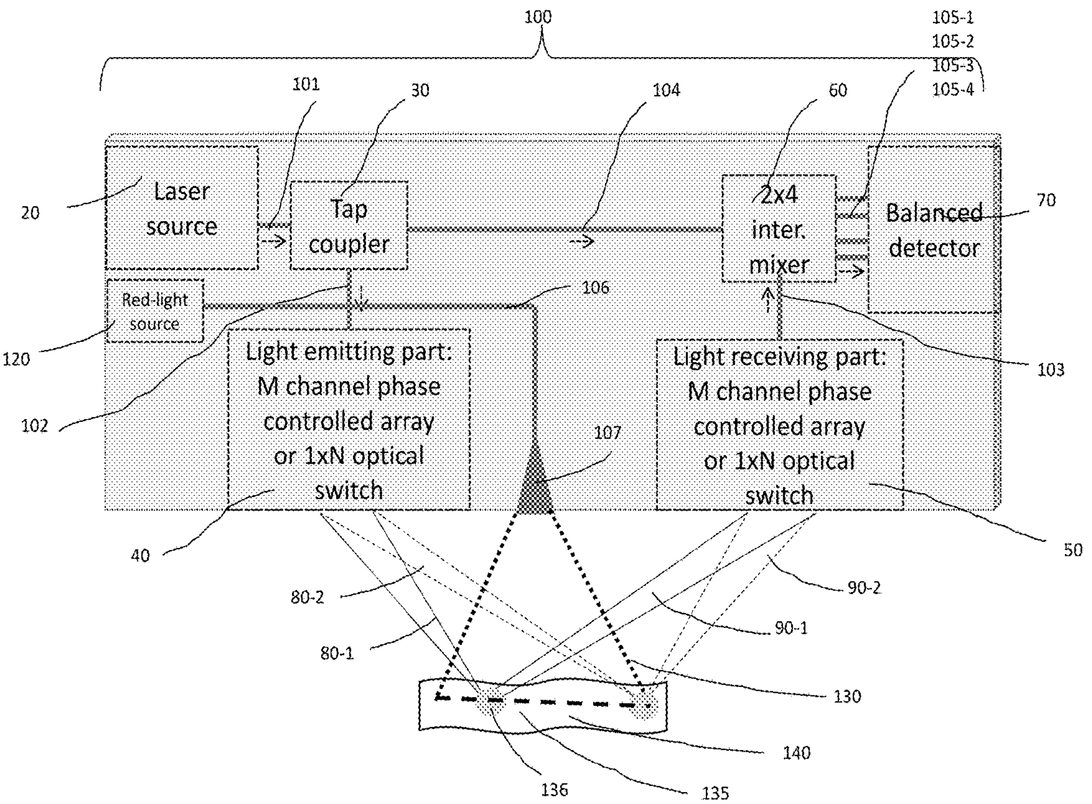
Publication Classification

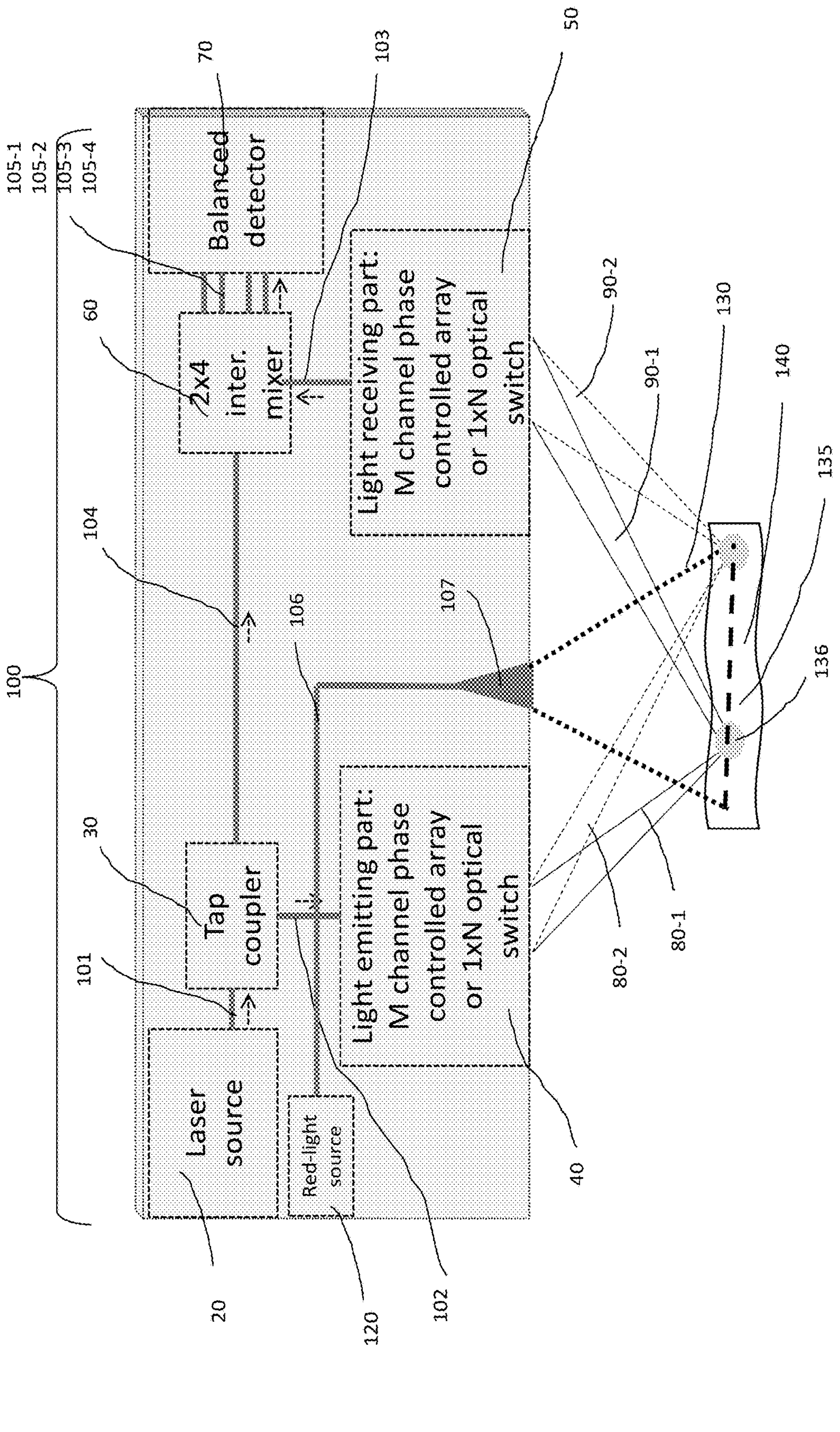
(51) **Int. Cl.**
A61B 5/024 (2006.01)
A61B 5/00 (2006.01)
A61B 5/021 (2006.01)
A61B 7/04 (2006.01)

(52) **U.S. Cl.**
CPC *A61B 5/02416* (2013.01); *A61B 5/0022* (2013.01); *A61B 5/742* (2013.01); *A61B 7/04* (2013.01); *A61B 5/02108* (2013.01)

(57) **ABSTRACT**

The object of the present invention is to disclose a novel optical miniaturized handheld medical device for convenient monitoring and/or data collection of detailed signals on human cardiovascular function. The implementation consists of a number of advanced technologies, including interferometric detection, phase controlled focusing beam steering, auto-tracking scheme and algorism, and integrated optical chip assembly to enhance the device's performance and miniaturization. Briefly, this handheld medical device directs a single or dual output laser beam(s) onto certain skin surface to detect the surface vibration velocity at the point where the laser hits the surface. The skin surface vibrates in response to cardiovascular signals, such as blood pressure pulses, turbulent blood flow through narrowed arteries, pumping actions of the heart, or the closure of the heart valves etc. The miniaturized apparatus thus is capable of detecting these signals for the assessment of cardiovascular functions in both healthy and disease conditions.





100
105-1
105-2
105-3
105-4
70
Balanced detector
103
50
60
2x4 inter. mixer
Light receiving part: M channel phase controlled array or 1xN optical switch
90-2
90-1
130
140
135
104
106
107
136
30
Tap coupler
101
Light emitting part: M channel phase controlled array or 1xN optical switch
80-2
80-1
Laser source
Red-light source
40
20
120
102

FIG.1

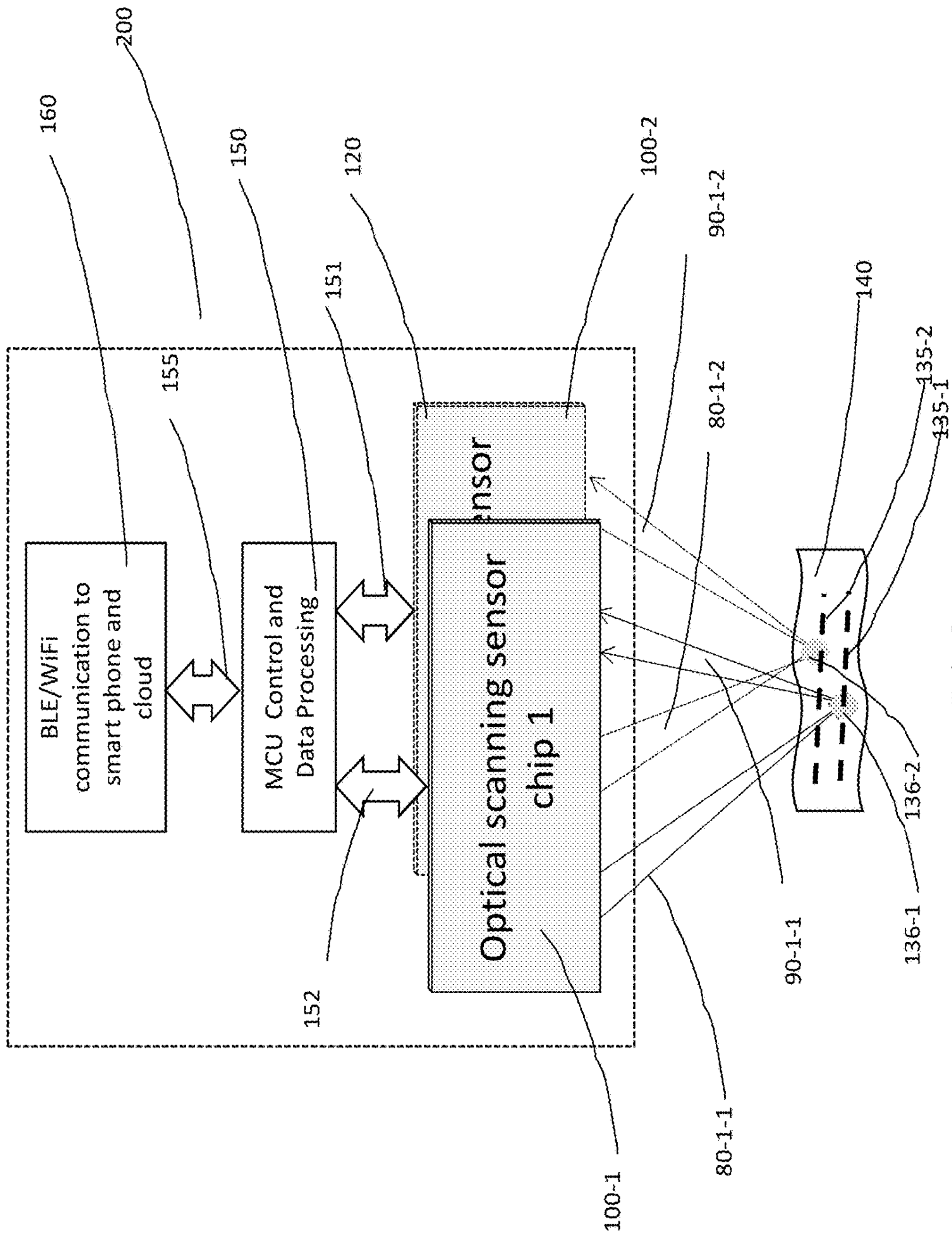

200
160
150
120
100-2
90-1-2
151
155
80-1-2
140
135-2
135-1
BLE/WiFi communication to smart phone and cloud
MCU Control and Data Processing
Optical scanning sensor chip 1
ensor
152
100-1
80-1-1
90-1-1
136-1
136-2

FIG. 2

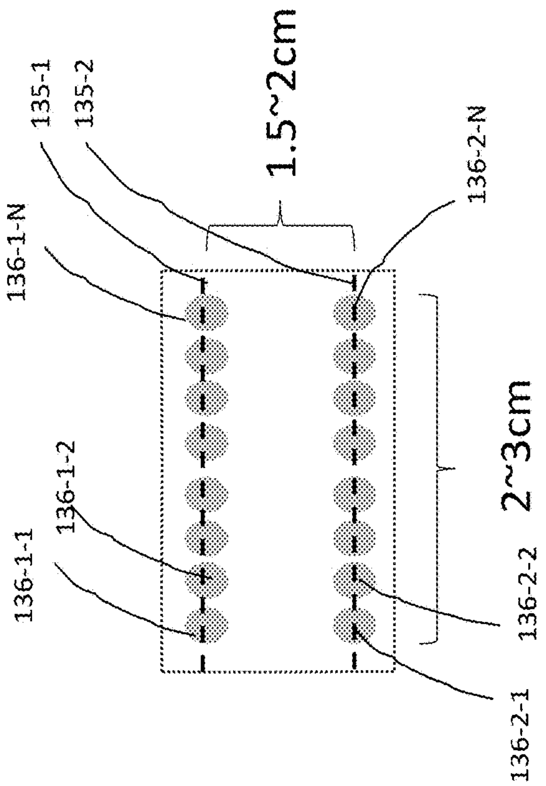

1.5~2cm
135-1
135-2
136-1-N
136-2-N
136-1-2
136-1-1
2~3cm
136-2-2
136-2-1

FIG. 4

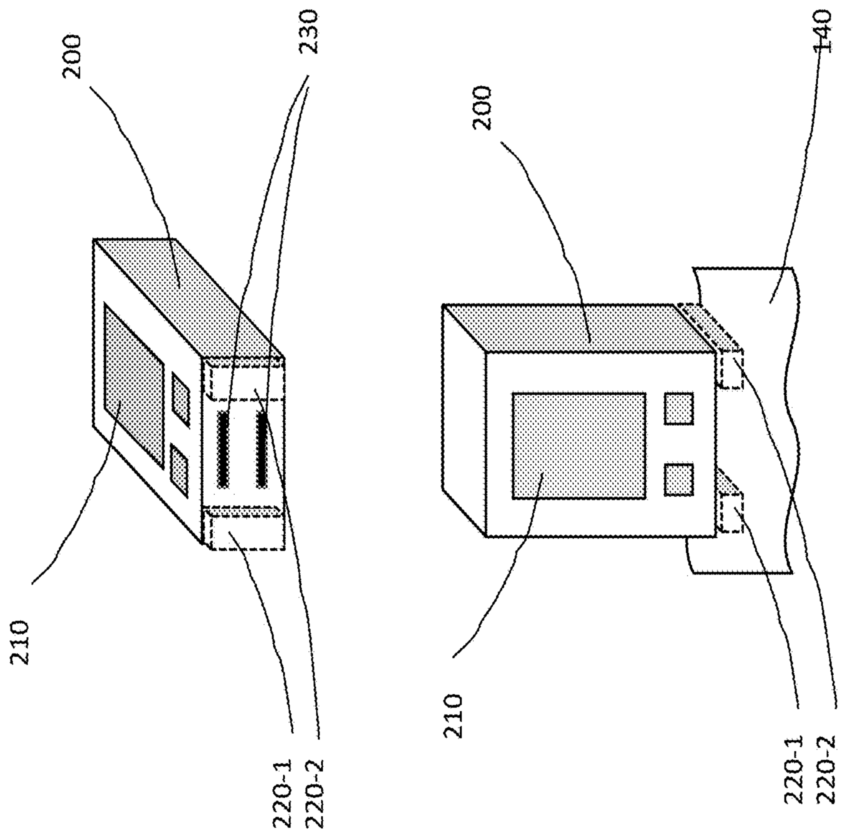

200
230
210
220-1
220-2
200
140
210
220-1
220-2

FIG. 3

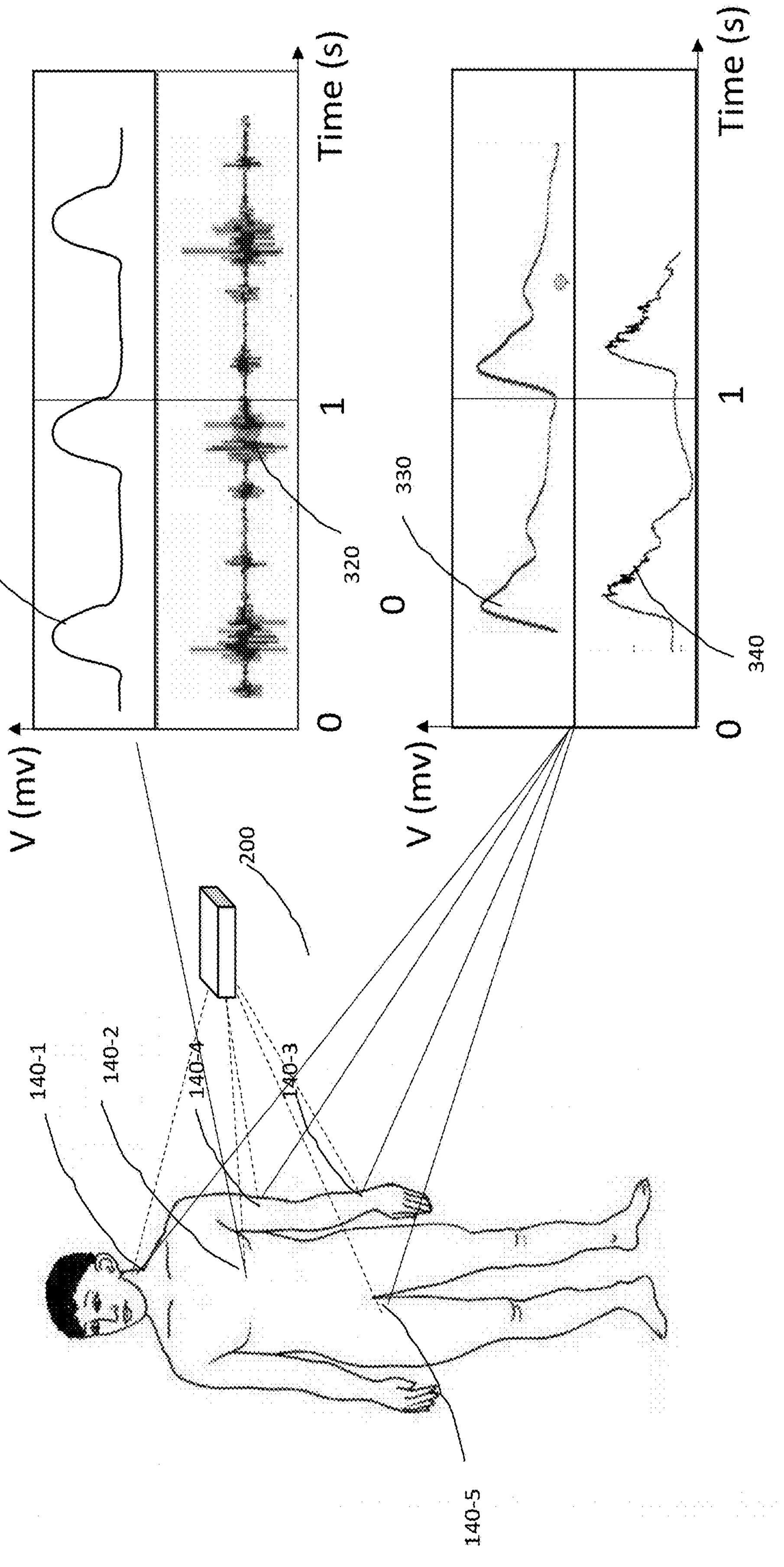

V (mv)
Time (s)
0
1
310
320
V (mv)
Time (s)
0
1
330
340
200
140-1
140-2
140-4
140-3
140-5

FIG. 5

NOVEL OPTICAL INTERFEROMETRIC SCANNING DETECTOR FOR CARDIOVASCULAR FUNCTION MONITORING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present non-provisional application is a continuation-in-part of U.S. Non-Provisional patent application Ser. No. 15/146,354, filed May 4, 2016, entitled "Interferometric focusing beam optical cardiovascular sensor", which claims priority and other benefit from U.S. Provisional Patent Application Ser. No. 62/174,624, filed Jun. 12, 2015, and of U.S. Non-Provisional patent application Ser. No. 15/235,656, filed Aug. 11, 2016, entitled "1D laser beam guiding and tracking system and method for interferometric focusing beam optical cardiovascular sensor".

BACKGROUND OF THE INVENTION

[0002] The present invention relates generally to a portable apparatus that is designed as a miniaturized handheld device for cardiovascular function monitoring that can be used in either hospital or household. More specifically, the cardiovascular function monitor presented here is capable of detecting movements of skin surface due to the contraction (s) of the heart or blood vessels; or to turbulent blood flow through the heart or the blood vessels. The implementation of such portable equipment is based on a non-invasive method using optical interferometric laser scanning beam as the probing signal published in U.S. patent application Ser. No. 15/146,354, filed May 4, 2016, entitled "Interferometric focusing beam optical cardiovascular sensor".

[0003] Detection and monitoring of the activities of the heart or the blood vessels provide important physiological and pathological information on the cardiovascular system function of human body. Pumping action of the heart produces beats and closing of heart valves produces sounds, movement of the arteries contributes to the propagating pulses and turbulent blood flow through narrowed arteries produces arterial bruit [e.g., the blowing/swishing sound in a stenosed (narrowed) carotid artery] and so on. These cardiovascular signals which reflect functions of the Circulatory (Cardiovascular) System can be assessed by modern techniques, such as ultrasound-visualization, electro-cardiography (ECG), or auscultation with a stethoscope etc. However, none of these methods provides complete information on both the heart and the blood vessels. Also, there are numerous situations under which ordinary techniques are hampered, e.g., the heart sound(s) collected using an ordinary stethoscope is (are) faint or not even audible as the result of ambient noises. Furthermore, as cardiovascular diseases need early detection of the risks, none of these methods provides early enough diagnosis unless severe events bring the patients to the hospital. Therefore, it is the broad object of the present invention to provide a novel portable optical scanning detection system, wherein and whereby, cardiovascular signals as a result of the contractions of the heart or blood vessels, or turbulent blood flow through the heart chambers, valves, or blood vessels, could be detected and quantified, such that abnormalities, if any, of the cardiovascular function could be identified, quantitatively, at early-stage.

[0004] The following U.S. patents describe various prior art systems related to the above discussed problems but do not satisfy the long felt but unsolved need for portable, miniaturized multi-functional device that can perform multiple detection schemes at a minimum cost level:

[0005] U.S. Pat. No. 7,024,001, issued Apr. 4, 2006, to Tsutomu Nakada, Tokyo, discloses a laser based stethoscope that a radiation/light-receiving fiber, serving as a probe part for noninvasively irradiating with near-infrared light, is applied to the diseased part so as to measure, e.g., a change of the cerebral circulation blood flow. In this design, three semiconductor laser light sources with wavelengths λ=760, 800, 830 nm are used and applied to the diseased part, the reflection data from the diseased part is processed by a control device. The doctor can then "make a diagnosis with the doctor's ears by hearing with a receiver the change as the change of the frequency of the sound the pitch and volume of which are constant." This invention helps the detection on blood flow turbulence, but lacks solution on detecting other vital cardiovascular events, such as heart beat, heart sound, pulse wave, etc.

[0006] U.S. Pat. No. 7,128,714, issued Oct. 31, 2006, which proposes a non-contact method and an apparatus for continuously monitoring a physiological event in human or animals, namely blood pressure, involves utilizing a laser-based interferometer system to produce a waveform that is representative of continuous blood pressure in a subject. The invention utilizes a laser Doppler vibrometer which is substantially perpendicular to a skin surface of the subject wherein the skin surface is moveable in response to blood pressure. The principle and implementation of the invention is novel though its size, cost and applications are limited due to the traditional laser Doppler vibrometers.

BRIEF SUMMARY OF THE INVENTION

[0007] The present patent application disclosed here provides the most comprehensive cardiovascular function monitoring and meets portable device criteria in terms of size and cost.

[0008] The disclosed portable apparatus consists of three major parts: 1) An optical interferometric scanning sensor chipset; 2) A control and data processing unit; and 3) A communication unit.

[0009] In an exemplary embodiment, the optical interferometric scanning sensor chipset of the apparatus is manufactured with integrated photonics technology, with multiple functional units integrated on a single chip:

[0010] Laser source, which generates the 1st laser light and makes the laser light be coupled into optical waveguide;

[0011] Tap coupler, which receives the 1st laser light and splits it into the 2nd laser light and reference laser light;

[0012] Light emitting part, which receives the 2nd laser light and forms the 3rd laser light that shines on the targeted scanning skin surface. It could have two different hardware implementations to achieve 1D laser beam scanning, either 1D angle scanning or 1D position scanning;

[0013] Light receiving part, which receives the reflected light (the 4th laser light) from the targeted skin surface and forms the 5th laser light. The light receiving part has the similar hardware implementation as the light emitting part that has the capability to do laser beam scanning, either 1D angle scanning or 1D position scanning.

[0014] 2×4 interferometric mixer, which receives the 5^{th} laser light and reference light, and generates the beating signals as the 6^{th} laser light.

[0015] Balanced detector, which receives the 6^{th} laser light and converts the 6^{th} laser light into analog electrical signals. The received analog electrical signals are then amplified by TIAs and converted into digital signals by ADCs. Through DSP, the magnitude and phase of the cardiovascular signals can be recovered.

[0016] In an exemplary embodiment, the control and data processing unit performs the general control of optical interferometric scanning sensor chipset as well as the steering/switching and tracking algorithm for both emitting and receiving laser beams. It also does the preliminary data processing before sending the data out to either nearby paired smart devices (phones, tablets etc.) or the clouds.

[0017] In an exemplary embodiment, the communication unit is responsible for communicating with nearby paired smart devices (phones, tablets etc.) or clouds, through wireless technology, such as BLE, Wi-Fi, or LTE.

[0018] The interferometric sensing chipset is based on an integrated optical waveguide platform with built-in hybrid-packaged laser source and I/Q balanced receivers. A laser beam guiding and tracking scheme is also implemented to improve the tolerance to position shift due to human body movement during measurements. Thus, it has sensitivity advantages over other methods as well as size and cost.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The present invention is illustrated and described herein with reference to the various drawings of exemplary embodiments, in which like reference numbers are used to denote like system components/method steps, as appropriate.

[0020] FIG. **1** is a schematic diagram of the design for the integrated optical scanning sensor chipset with multiple functions, such as Interferometric focusing beam steering, I/Q balanced detection, etc., for the purpose of detection and monitoring of the cardiovascular signals.

[0021] FIG. **2** is a schematic diagram of an exemplary implementation of the miniaturized device comprising of three major parts for convenient cardiovascular signals monitoring.

[0022] FIG. **3** is a conceptual drawing illustrating the possible mechanical design of the miniaturized device with two optical scanning sensors implemented.

[0023] FIG. **4** is a schematic diagram of the scanning zone and location of the optical scanning beam on the targeted scanning skin surface.

[0024] FIG. **5** is a schematic diagram of the potential areas of human body to which the miniaturized device can be applied and exemplary signals at the chest wall (for heart) or at certain skin surfaces (for blood vessels).

DETAILED DESCRIPTION OF THE INVENTION

[0025] Consistent with the inventions of "Interferometric focusing beam optical cardiovascular sensor", U.S. patent application Ser. No. 15/146,354 and "1D laser beam guiding and tracking system and method for interferometric focusing beam optical cardiovascular sensor", U.S. patent application Ser. No. 15/235,656, this invention describes the implementation of a miniaturized handheld medical device for the cardiovascular signals monitoring purpose.

[0026] Referring to FIG. **1**, this is an integrated optical waveguide chipset **100** that consists of 6 major functional parts: the laser source **20**, the tap coupler **30**, the light emitting part **40**, the light receiving part **50**, the 2×4 interferometric mixer **60** and the 2-pair balanced detectors **70**. On the optical chip, laser source **20** generates the 1^{st} laser **101**. The tap coupler **30** receives the 1^{st} laser and splits it into the 2^{nd} laser **102** and the reference light **104**. The 2^{nd} laser **102** is received by the light emitting part **40** and converted into the 3^{rd} laser **80**, where the 3^{rd} laser can shine on the targeted scanning skin surface **140** at controllable output angle or output position. Its phase is constant but the amplitude can be dithered as a function of time t for laser beam guiding and tracking purpose. The diffused reflection light from the targeted scanning surface **140**, the 4^{th} laser light **90**, has an angle dependent distribution. At the targeted scanning skin surface **140**, the phase of 4^{th} laser light **90** is modulated by local cardiovascular event(s). Only a portion of the 4^{th} laser light **90** with optimized reflection angle or position can be received or collected by light receiving part **50**. The light receiving part **50** converts the 4^{th} laser light **90** into the 5^{th} laser light **103**. The 5^{th} laser light **103** is mixed with the reference light **104** inside the 2×4 interferometric mixer **60**, generating the 6^{th} laser light **105**, which contains a set of optical beating signals +I/−I **105-1**, **105-2**, +Q/−Q **105-3**, **105-4**. In balanced detectors **70**, the 6^{th} laser light **105** is converted into electrical signals.

[0027] As an option, the visible red-color light source **120** generates the 1^{st} red-color light **106**. The slab waveguide **107** receives the 1^{st} red-color light **106** and shines it onto the targeted scanning skin surface **140**, forming a visible 1D linear marker on the targeted skin surface **140**.

[0028] The system diagram of the proposed miniaturized medical device for cardiovascular signals monitoring can be found in FIG. **2**. The miniaturized device **200** consists of three major parts: 1) Two optical scanning sensor chipsets **100-1** and **100-2**, each to detect a linear targeted skin surface with distance about 1.5-2 cm. In combination, they work together to collect timing sensitive waveforms for key parameters calculation, such as local pulse wave velocity (PWV). Normally, these two optical scanning sensors are integrated into one chipset; 2) The control and data processing unit **150**, performs the general control of optical interferometric scanning sensor chipset as well as the steering/switching and tracking algorithm for both emitting and receiving laser beams. It also does preliminary data processing before sending the data out to either nearby paired smart devices (phones, tablets etc.) or the clouds; 3) The communication unit **160** is responsible for the communication between the miniaturized medical device and nearby paired smart devices (phone, tablet etc.) or remote clouds through BLE, Wi-Fi or LTE.

[0029] Referring to FIG. **3**, the conceptual design of the miniaturized medical device **200** could be a palm size rectangular prism. At the bottom end, there are two open slots **230** serving as open windows for two scanning laser beams, which are bout 1.5-2 cm apart. It may also have two supporting structures **220-1** and **220-2** with suitable materials as the buffer between the miniaturized medical device **200** and the target scanning skin surface **140**. On the front side, it may have one LCD display and few buttons **210** for device control and communication purpose.

[0030] Referring to FIG. **4**, with two built-in optical scanning sensors **100-1** and **100-2**, the miniaturized device **200** can perform laser beam steering and scanning along the two separate lines, marked by visible red-color lights **135-1** and **135-2**. As the emitting laser beam **80** of each optical scanning chipset can be steered or switched to N directions in 1D, the device can scan multiple spots **136-1-1**, **136-1-2**, . . . **136-1**-N, and **136-2-1**, **136-2-2**, . . . **136-2**-N, simultaneously, on the targeted scanning skin surface.

[0031] Referring to FIG. **5**, it illustrates that this miniaturized device **200** can be attached to multiple areas of human body for different detecting purposes, such as 1) the neck (for carotid artery); 2) forearm (for brachial artery) or wrist (for radial artery); 3) leg (for femoral artery) or ankle (for dorsalis pedis artery); or 4) the chest or thorax (for the heart). At the chest, the apparatus could detect the skin movement **310** due to the pumping action of the heart or **320** to the closing of the heart valves (heart sounds). Whereas at the neck or the extremities, the apparatus detects the skin movement **330** due to pressure-related artery displacement resulting in pulsating waveforms or **340** to turbulent blood flow through stenosed (narrowed) arteries, wherein the extent and accurate position of the stenosis can be calculated and located.

What is claimed is:

1. An apparatus or method for detecting movement (vibration signal) on human skin surface for cardiovascular function monitoring, comprising: an integrated optical interferometric scanning system with self-tracking function; a control and data processing unit; and a communication unit.

2. The apparatus or method of claim **1**, wherein said integrated optical interferometric scanning system with self-tracking function comprises:

A laser beam toward said skin surface of said subject and a reflected laser beam detected by a laser interferometer configured to detect said reflected laser beam and through said detection, determining one or more variables related to the vibration of said targeted skin surface; and

A laser beam guiding and tracking scheme based on angle or position steering to locate said blood vessel steers said laser beam to said sensing area and locks said laser beam to said targeted location under all circumstances.

3. The apparatus or method of claim **1**, wherein said control and data processing unit is configured for general system control and preliminary data processing of said vibration signals of said skin surface.

4. The apparatus or method of claim **1**, wherein said communication unit is configured for transferring and displaying said vibration signals of said skin surface to nearby paired smart devices (phones, tablets etc.) or clouds, through wireless technology, such as BLE, Wi-Fi, or LTE.

5. An apparatus or method for monitoring the cardiovascular function by analyzing the cardiovascular signals extracted from said vibration signals collected through a miniaturized handheld device that is based on integrated optical interferometric scanning technology.

6. The apparatus or method of claim **5**, wherein said cardiovascular signal is arterial blood pressure-related pulse wave.

7. The apparatus or method of claim **5**, wherein said cardiovascular signal is turbulent sound produced by blood flow through a narrowed artery.

8. The apparatus or method of claim **5**, wherein said cardiovascular signal is the rhythm and/or synchronicity of the heart beats (contractions).

9. The apparatus or method of claim **5**, wherein said cardiovascular signal is heart sound(s) produced by the closure of the heart valve(s) or the filling of the heart.

10. The apparatus or method of claims **5-9**, wherein the biometric of said cardiovascular signal is the velocity of said skin surface vibration as a function of time.

11. The apparatus or method of claim **6**, wherein said cardiovascular signal is pulse wave, PWV, and further comprising the step of producing blood pressure measurement including determination of pulse rate, systolic and diastolic blood pressure, dicrotic notch, and duration of systole and diastole by plotting skin surface displacement as a function of time.

12. The apparatus or method of claim **8**, wherein said cardiovascular signal is heart beat and further comprising the step of determination of heart rate, synchronicity of the left and right atria, the left and right ventricles, and the walls of ventricles by plotting skin surface displacement as a function of time.

13. The apparatus or method of claim **9**, wherein said cardiovascular signal is heart sound(s), wherein the first sound produced by the closure of the mitral and tricuspid valves, the second by the closure of the aortic and pulmonic valves, the third by the early, passive diastolic filling of the ventricles, and the fourth by the late, active filling of the ventricles due to atrial contraction, and other extra-heart sounds that cause the movement/vibration of the chest wall by plotting skin surface displacement as a function of time during cardiac cycles.

14. The apparatus or method of claims **5-13** further comprise general system control and preliminary data processing of said cardiovascular signals, wherein the biometric of the cardiovascular signal is the velocity of the skin surface vibration as a function of time.

15. The apparatus or method of claims **5-13** further comprise transferring and displaying said cardiovascular signals on a remote device, wherein the biometric of the cardiovascular signal is the velocity of the skin surface vibration as a function of time.

* * * * *

patsnap

专利名称(译)	用于心血管功能监测的新型光学干涉扫描检测器		
公开(公告)号	US20180192898A1	公开(公告)日	2018-07-12
申请号	US15/403184	申请日	2017-01-11
[标]申请(专利权)人(译)	张进 钟山 陈伟 朱中华 吴磊		
申请(专利权)人(译)	张，金 钟，SHAN 陈韦 朱，中华书局 吴雷		
[标]发明人	ZHANG JIN ZHONG SHAN CHEN WEI ZHU ZHONGHUA WU LEI		
发明人	ZHANG, JIN ZHONG, SHAN CHEN, WEI ZHU, ZHONGHUA WU, LEI		
IPC分类号	A61B5/024 A61B5/00 A61B5/021 A61B7/04		
CPC分类号	A61B5/02416 A61B5/0022 A61B5/742 A61B7/04 A61B5/02108 A61B5/0064 A61B5/02133 A61B5/02444 A61B5/1102		
其他公开文献	US10561392		
外部链接	Espacenet USPTO		

摘要(译)

本发明的目的是公开一种新颖的光学小型化手持式医疗设备，用于方便地监测和/或收集关于人类心血管功能的详细信号。该实现包括许多先进技术，包括干涉检测，相位控制聚焦光束控制，自动跟踪方案和算法，以及集成光学芯片组件，以增强设备的性能和小型化。简而言之，该手持式医疗设备将单输出或双输出激光束引导到某些皮肤表面上，以检测激光撞击表面的点处的表面振动速度。皮肤表面响应于心血管信号而振动，例如血压脉冲，通过狭窄动脉的湍流血流，心脏的泵送动作，或心脏瓣膜的闭合等。因此，小型化装置能够检测这些信号。评估健康和疾病状况下的心血管功能。