Design and Study of a Wearable Non-Invasive Photoacoustic Glucose Monitor

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Abstract: This paper relates to a wearable non-invasive photoacoustic blood glucose monitor with a display, control buttons, controller, battery and measurement box in a wearable housing. The wearable case is fitted with a strap that is worn on the wrist of the person being tested. The photoacoustic excitation source and the optical lens system produce a focused laser beam that passes through the hollow multi-ring array sensor and is directed towards the blood vessels in the wrist to achieve continuous A-shaped dynamic focus scanning photoacoustic glucose detection, providing photoacoustic glucose results at multiple sites in the depth direction of the wrist. This paper has the advantages of being compact, portable, easy to operate, enabling real-time monitoring of photoacoustic glucose, non-invasive during testing, eliminating the need to extract blood and provide test strips, and avoiding cross-contamination and environmental effects.
Keywords: Blood Glucose Monitoring; Non-Invasive; Wearable; Photoacoustic; Instrumentation

1. Introduction

At present, blood glucose testing is still commonly performed by invasive or minimally invasive interventional methods, which require minute amounts of peripheral blood and corresponding test strips. The future direction of development should be non-invasive non-invasive blood glucose testing techniques, such as photoacoustic analysis, spectroscopy, Raman spectroscopy, light scattering spectroscopy and optical polarisation spectroscopy. There are still many difficulties with current photoacoustic analysis methods, such as the need to achieve non-destructive detection, the energy of the incident laser cannot exceed the threshold value, so effectively improving the excitation efficiency of photoacoustics is an urgent problem to be solved. In addition, photoacoustic detection also mostly uses solid-state lasers as the excitation source, and there are certain difficulties in the integration and miniaturisation of the system.

Due to the single detector as the sensing part, photoacoustic excitation and sensing can not achieve coaxial confocal structure, so the efficiency of photoacoustic excitation and detection is not high, need a larger power solid-state laser to provide photoacoustic excitation energy, or need thousands of signal averaging to improve the signal-to-noise ratio, and the large volume of solid-state laser can not achieve the integration of excitation and sensing and miniaturization, multiple signal averaging greatly reduces the The large size of the solid-state laser does not allow for the integration and miniaturisation of excitation and sensing, multiple signal averaging greatly reduces the temporal resolution of the system, and both forward and lateral detection modes lack practical ease of operation, limiting the prospects for practical application.

2. Wearable non-invasive photoacoustic glucose monitor design

The technical problem to be solved in this paper is to design a wearable non-invasive blood glucose monitor with compact structure, easy portability and simple operation, which can provide simultaneous photoacoustic blood glucose monitoring results at multiple loci in the wrist depth direction. The overall framework of the specific design is shown in

Figure 1.

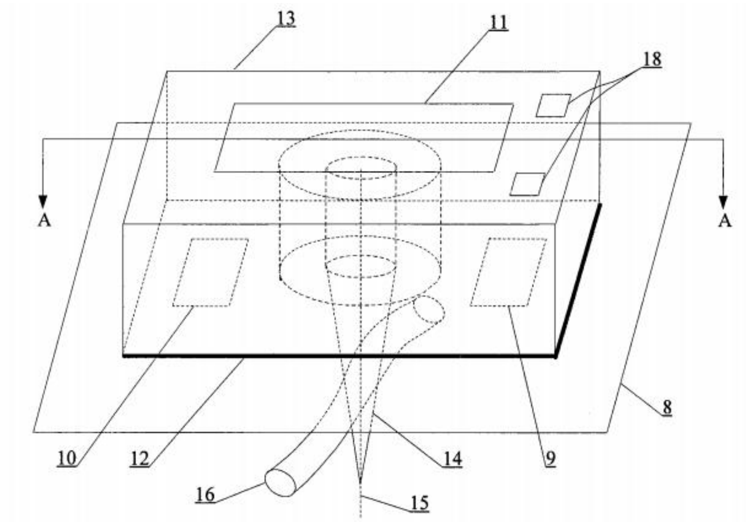

Figure 1 Overall framework of the wearable non-invasive photoacoustic glucose monitor

This paper designs a wearable non-invasive photoacoustic blood glucose monitor, characterized in that the surface of the housing is provided with a display and control buttons, the bottom surface of the housing is a multi-layer bonding plate, the measurement box is placed on the multi-layer bonding plate, the measurement box is provided with a hollow acoustic insulation layer and an acoustic liner; on top of the acoustic insulation layer is a semiconductor laser tube, below the semiconductor laser tube is a Fourier lens, the Fourier lens The centre of the semiconductor laser tube, the Fourier lens, the light-transmitting protective film and the hollow multi-loop array sensor are all located on the same central axis and are integrated in the measurement box, forming an integrated coaxial confocal structure, which can effectively reduce the laser energy requirement while increasing the detection depth; the side of the measurement box is equipped with a controller and a battery. The hollow multi-ring array sensor is connected to the terminal block of the controller through the wires of each ring. The housing is of a wearable type, fitted with a strap to be worn on the wrist of the person being tested. Said semiconductor laser tube is a semiconductor pulsed laser diode, operating at one or more wavelengths in the ultraviolet to infrared range. Said semiconductor laser tube and Fourier lens form a photoacoustic excitation source and optical path lens system to produce a focused laser beam that passes through the light-transmitting protective film and the hollow inner ring of the hollow multi-ring array sensor and is directed at the blood vessels within the wrist. Said hollow multi-ring array sensor is a hollow planar or concave-convex array made of piezoelectric materials, including lithium niobate, composite materials, piezoelectric ceramics or PVDF films; the hollow multi-ring array sensor uses serial or parallel real-time reception of photoacoustic signals in backward mode to achieve continuous A-shaped dynamic focus scanning of photoacoustic glucose detection, providing photoacoustic glucose results at multiple loci in the depth direction of the wrist.

3. Workflow of the wearable non-invasive photoacoustic glucose monitor

Under the trigger of the controller, the semiconductor laser tube is excited to produce a pulsed laser whose wavelength, pulse width and repetition frequency can be selected as required.

Laser energy is collimated and focused through the optical lens and radiated through the protective film to the blood vessels under the skin of the wrist, blood sugar and other functional groups absorb the light energy to excite the photoacoustic signal; the controller simultaneously triggers the multi-ring array sensor backward mode to detect the photoacoustic signal to achieve the excitation and sensing of the photoacoustic signal.

By processing the collected photoacoustic data through certain algorithms, the continuous A-shaped dynamic focus scanning detection of photoacoustic blood glucose in the depth direction can be achieved, and the photoacoustic blood glucose results of multiple loci in the depth direction of the wrist can be obtained.

4. Summary

The method in this paper integrates the backward receiving mode of photoacoustic, excitation and sensing processing, effectively realising a miniaturised and practical wearable system structure, with the advantages of compact structure, easy portability, simple operation, enabling real-time monitoring of photoacoustic blood glucose, non-invasive detection, no need to extract blood and provide test strips, avoiding cross infection and environmental impact. In addition, this paper combines the photoacoustic excitation source, the optical path lens system and the multi-ring array sensor to form a coaxial confocal structure, which can greatly improve the photoacoustic excitation and sensing efficiency, effectively reduce the laser energy requirement while increasing the detection depth, achieve continuous A-type dynamic focus scanning detection of photoacoustic glucose, and provide photoacoustic glucose results at multiple loci in the wrist depth direction.

References

[1] Xiao Y. The "blood sucker" can test blood with a single bite[J]. Environment and Life, 2017(08):95.

[2] Sun J. Can wearing a "watch" cure "three highs"? [J]. Health Expo, 2017(05): 30-31.

[3] CEVA low-power Bluetooth IP drives NXP QN9000 series Bluetooth Smart SoC[J]. Microcontroller and Embedded System Applications, 2015, 15(10):88.

[4] Zhang YC, Jin XY, Shen JF. Status and technology analysis of wearable health monitoring devices[J]. Journal of Medical Informatics,2015,36(09):2-7.

[5] Gao HY. Multi-device ride on the Apple Watch mobile medical hitchhiker [J]. China Pharmacy, 2015(12):54-55.

[6] Xin X, Panorama. Medical care is also mobile[J]. Health Home,2015(05):31-41.

[7] Bai TM, Wang JY. Caring for the elderly in the name of intelligence[J]. Mobile Information,2014(11):94-101.

[8] Benzinga. Sano mobile phone smart blood glucose meter[J]. China Journal of Medical Devices, 2014, 38(04):294.

[9] Ye YM. Smart applications on watches[J]. Integrated Circuit Applications, 2011(06):36-37.

[10] Liu XF, Liu C. A comparison of several current ambulatory glucose monitoring systems[J], International Journal of Endocrinology and Metabolism, 2009(03): 197- 200.

[11] Zheng HL. Design of a portable blood glucose detector [D]. Hubei University of Technology, 2009.

[12] Yang GZ. Watch-based non-invasive, real-time and continuous blood glucose monitoring devices are on the horizon[J]. DOI:10.15971/j.cnki.cmdi.2005.04.018.

[13] Pang XH, He XW, Gu W. Clinical application of watch-type glucometer in Chinese diabetic patients[J]. Chinese Journal of Endocrinology and Metabolism,2004(04):369-371.

[14] Cao Fu. New breakthroughs in medical technology[J]. Medical and Health Care Instruments,2002(Z3):68-71.

[15] Gan JL, Yang HH, Huang WM, Liu H. Non-invasive watch for blood glucose determination[J]. Foreign Med. Journal of Nursing, 2000(04):186.

[16] Chen HY. Watch-type blood glucose monitor[J]. China Journal of Medical Devices,1999(04):237.

[17] Seeking truth. A wide variety of medical and health care products for home use [J]. Journal of Electrical and Commercial Products Science and Technology, 1996 (04):13.

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