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Development of a sensor for blood flow measurement Of Human using Laser Doppler Flowmetry

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Abstract— **In this paper, we addresses the development of a sensor for measurement of blood flow in humans based on LDF (Laser Doppler Flowmetry) technique. The size of sensor is very small and is one of the smallest-sized blood flow meters, with no wired line. The structure of the sensor chip consists of two silicon cavities with a photo diode and a laser diode, which was achieved using the micro electromechanical systems technique, resulting in its small size and significantly low power consumption. In addition, we introduced an intermittent measuring arrangement in the measuring system to reduce power consumption and to enable the sensor to work longer. Blood flow measurement is important because an adequate amount of blood supply is necessary for the proper functioning of all body organs as blood carries all the nutrients and oxygen that our body needs to stay healthy. Various diseases cause an impaired supply of blood to the organs. The measurement of the blood flow can therefore provide essential information for the diagnosis of diseases. Since changes in blood flow occurs with the very initial stage of disease, with a fast, reliable and non-invasive blood flow measurement technique, the physicians would be provided with new options for early disease diagnosis. So using this sensor we can successfully & easily able to measure human blood flow.**

***Index Terms*— blood flow, laser Doppler, low power consumption, micro sensor, wireless.**

INTRODUCTION

Today it is common practice to measure human health information such as blood pressure, heart rate, and electrocardiogram (ECG) to detect health problems. This information is also utilized to define standards of human health. Motivated by these broad and important, applications we developed a sensor based on micro electromechanical systems (MEMS) techniques using laser Doppler flowmetry (LDF) as a noninvasive method of measuring blood flow. The sensor size is very small and the use of MEMS enables dramatically reduced power consumption although a blood flow sensor is of comparable size and also consumes little power, making it suitable to be mounted on a human. In studying blood flow data, we found strong evidence that blood flow is related to biomedical signals in humans, such as sympathetic and parasympathetic-related feelings, emotions, and drowsiness .we are also studying animal blood flow, because blood flow data are similarly representative of animal bio information. Animal blood flow data can be used in studies on animal living, quality control of domestic animals, and the development of veterinary science.

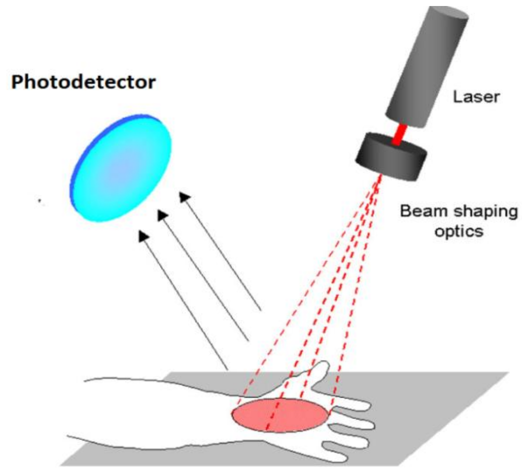


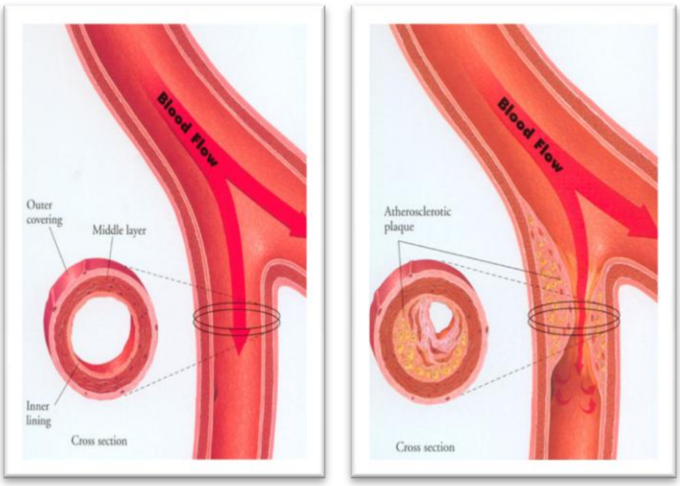
Fig1: Blood flow measurement using LDF

There is an urgent need to find effective methods for the early detection of avian influenza, which is of international importance. Birds infected with avian influenza show swelling and congestion in their feet, and it is believed that these symptoms may be reflected by blood flow. Therefore, detecting avian influenza is one application of using MEMS-LDF with birds also.

In the present study, we describe an integrated laser Doppler blood flow micrometer, which we have developed for use with humans. This device is wireless, weighs very less, and has low power consumption. We can easily find out blood flow rate of humans with this sensor.

II. What is Blood Flow?

- Blood flow is amount of blood moving through a vessel in a given time period.
- Blood flow is directly proportional to pressure differences, inversely proportional to resistance
- Blood flow helps to understand basic physiological processes and e.g. the dissolution of a medicine into the body.
- Blood flow and changes in blood volume, are usually correlated with concentration of nutrients and other substance in the blood.
- Also, Blood Flow measurement reflects the concentration of O_2



Normal blood flow velocity 1 m/s (Systolic, large vessel) 0.5 m/s

III. Types of blood flow measurement

The methods of blood flow measurement are divided into following two main types

1. Invasive methods
2. Non Invasive methods

Non Invasive methods are further classified in to following subtypes

- Ultrasound Doppler
- **Laser Doppler Flowmetry**
- Strain Gage Plethysmography
- Electric-Impedance Plethysmography
- Photoelectric Plethysmography
- Thermal Convection Probes

Similarly Invasive methods are further classified in to following subtypes

- Dye Dilution Method
- Thermal Dilution Method
- Radioisotopes

Out of this all methods we are going to study **Laser Doppler Flowmetry(LDF)**.First we see basic concept of Laser Doppler Flowmetry.

Laser Doppler Flowmetry (LDF) is a non-invasive method to estimate the blood perfusion in the microcirculation. The method was first introduced over 30 years ago and has undergone a continuous development since Laser Doppler Flowmetry (LDF) is an accurate and reliable method for assessing microcirculatory function. Through a series of in vitro and in vivo experiments, LDF output has been shown to be reproducible and to correlate with bone blood flow as estimated by other methods. The utility of the method in assessing meniscal, tendonous, and ligamentous perfusion has also been demonstrated. LDF has proven potential in clinical research in osteonecrosis, osteomyelitis, fracture healing, and other areas. With further refinements in application of the method and expanded definition of those factors which influence the output signal, LDF will continue to develop as an important tool for musculoskeletal experimental and clinical research .The principle of measurement is the same as with ultrasound Doppler

The laser parameter may have e.g. the following properties:

5 mW
He-Ne-laser
632,8 nm wavelength

The moving red blood cells cause Doppler frequency 30 – 12 000 Hz. The method is used for capillary (microvascular) blood flow measurements.

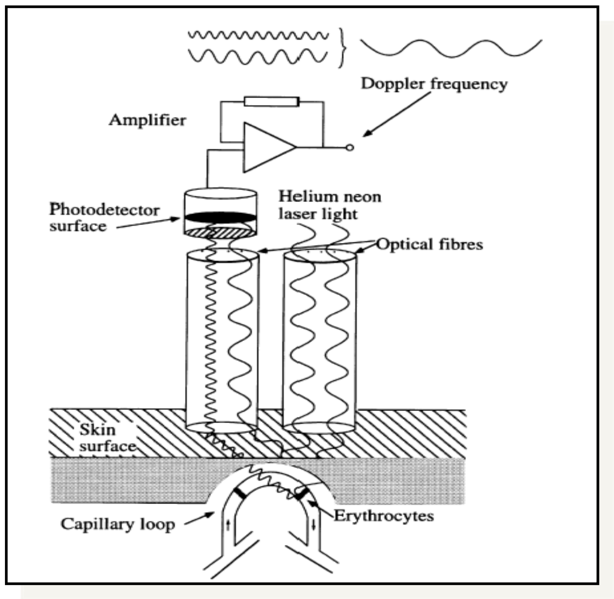


Fig 2: Laser doppeler flowmetry technique

IV. How does LDF work?

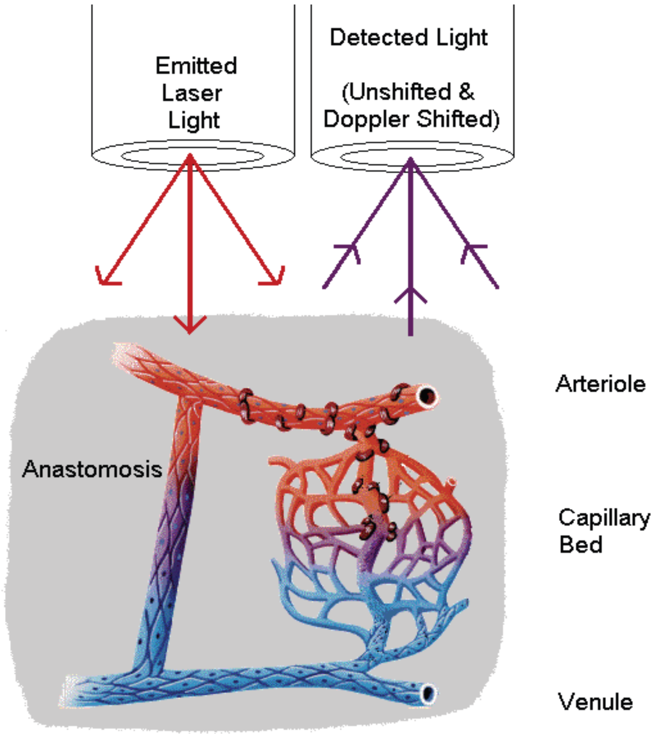


Fig 3: Working of LDF Technique

Fig 3 shows how actual LDF works. In LDF technique tissue is illuminated by low power laser light; the light is scattered by the static tissue structures and moving blood cells. Some portion of the laser light is Doppler shifted. Adjacent fiber optic detects un-shifted and Doppler-shifted light. Signal is processed to give a parameter related to tissue blood perfusion.

Following are some advantages of LDF technique

The LDF technique offers substantial advantages over other methods (e.g. 'micro beads') in allowing the continuous measurement of micro vascular blood perfusion. The LDF may be used non-invasively (since the probe is not actually required to touch the surface of the tissue) and in no way harms or disturbs the normal physiological state of the microcirculation. LDF is both highly sensitive and responsive to local blood perfusion and is also versatile and easy to use for continuous monitoring

- Continuous/real-time – response time 0.15s
- Sensitive to small changes
- May be used non-invasively , On skin or organ surface where exposed
- Small probe dimensions Minimal trauma used invasively

V. Development of Human Blood Flow Sensor

Fig. 4 shows the components of the MEMS-LDF developed for humans and the basic system for monitoring human blood flow. The sensor consists of a blood flow sensor probe, electric circuit box, and a coin battery. The electric circuit box includes an operational amplifier, a central processing unit (CPU), a transmitter, and an antenna. The sensor probe consists of a MEMS sensor chip, a laser-driving circuit, and an amplifying circuit for the photodiode (PD) signals. The PD signal is amplified in order to reduce interference from the conductive wire. To miniaturize the electric circuit box, we used a multilayer board while employing an interstitial via hole. The data obtained by the sensor are sent to a personal computer (PC) through a wireless link. Fig 5(a) shows the method of blood flow measurement and the structure of the sensor probe attached to the human's skin are shown in Fig. 5(a) the MEMS chip forms the sensor probe, which is a rectangular solid shape. Fig 5(b) shows two anisotropically etched silicon cavities with a distributed feedback laser diode (DFB-LD) chip consisting of a diode laser with a wavelength of 1310 nm mounted in one, a PD chip mounted in the other, and both housing through-hole electrodes. The PD is InGaAs uses a vertical cavity surface emitting laser (VCSEL) instead of a DFB-LD and a wavelength of 780 nm; we chose DFB-LD and 1310 nm because the laser beam of the DFB-LD has higher coherence than that of a VCSEL and 1310 nm light easily penetrates human skin. The sensor works on the principle of laser Doppler flowmetry monitoring of blood flow.The bottom silicon plate reflects the laser beam emitted vertically from the LD chip by means of a micro mirror, formed by depositing gold on the silicon facet.

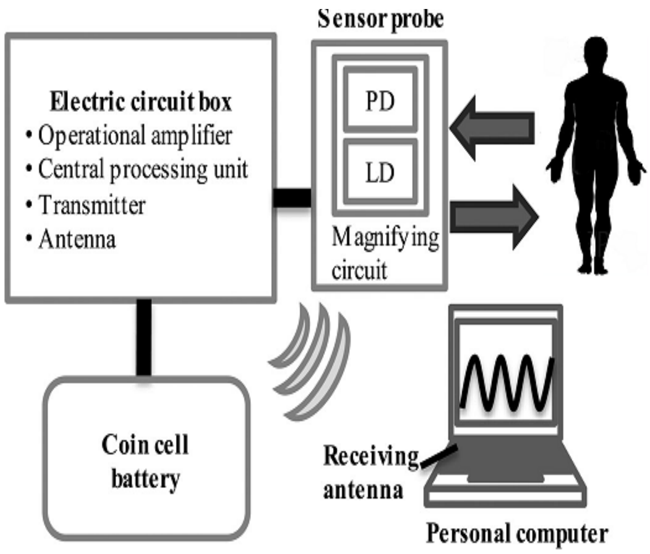
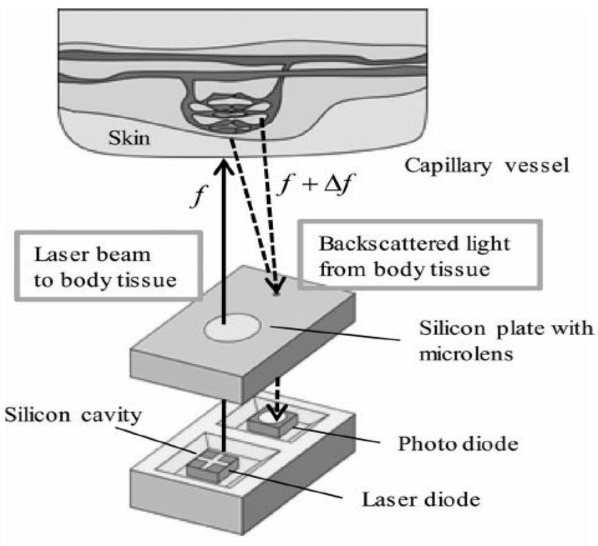


Fig 4 Components of MEMS-LDF developed for human and the basic system for monitoring human blood flow.

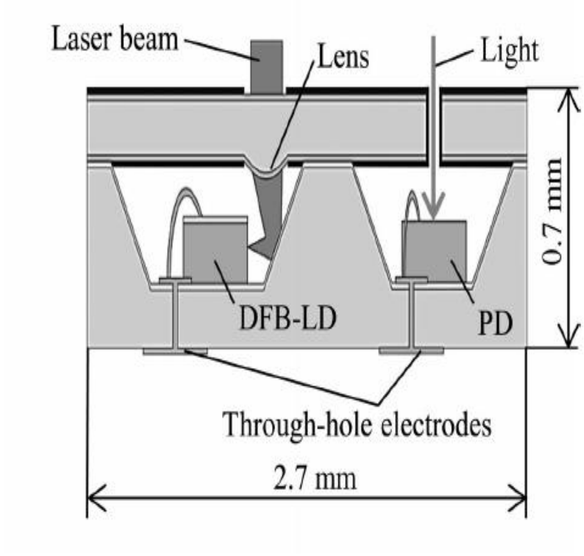
The reflected laser beam is collimated through a silicon lens and is directed to the human's skin, penetrating it to a certain depth. The light is scattered by red blood cells moving in capillary vessels and through static tissue. The backscattered light from the subject's skin passes through the window to the cavity where the PD detector is located. The frequency of the light scattered by the red blood cells changes slightly due to the Doppler effect, while the frequency of the light scattered by static tissue is unchanged with respect to the incident light. The relationship between the Doppler frequency Δf to the observed frequency and the medium velocity is given by

$$\Delta f = \frac{\overrightarrow{K} \cdot \overrightarrow{V}}{2\pi} = \frac{2n\nu}{\lambda} \cdot \sin\frac{\theta}{2} \cdot \cos\varphi$$

Where **K** is the scattering vector, **V** is the velocity vector, **n** is the refractive index of the medium, **λ** is the incident wavelength, **θ** is the scattering angle, and **ø** is the angle between **K** and **V**. This Doppler-shifted light and the unaffected light propagating through the hole create an interference pattern at the PD which modulates the light intensity, producing a beat signal. The PD converts the beat signal into photocurrent. The measurement depth in the skin strongly depends on the distance between the DFB-LD and PD. This distance in the MEMS-LDF device is 1.0 mm, and the device could measure blood flow at a depth of around 0.8 mm. Fig. 6 shows the electrical circuit process for the calculation of blood flow. In order to reduce data transmission and limit power consumption, the blood flow is calculated *in situ* before data are sent to the computer. The raw data Sampling rate is 40 kHz, and we use an anti aliasing filter over the range of 20 –10 kHz.



(a)



(b)

Fig5. (a) Measurement principle and fundamental structure of the sensor probe attached to the human's skin. (b) Schematic cross-sectional view of the MEMS chip.

The PD detects scattered light from the cavity through a window, so there is no ambient light to consider. The final transmission rate of calculated data is 50 Hz. The photocurrent obtained by the PD on the MEMS chip is Fourier transformed, and the component frequencies of the beat signal ω and the power spectrum of the beat signal $P(\omega)$ are calculated. The first moment $\omega P(\omega)$ is integrated by ω as

$$\langle \omega \rangle = \int_0^\infty \omega P(\omega) d\omega$$

and **(ω)** is proportional to the product of the average velocities and the concentration of those blood cells moving closer to the body surface .We used this value to signify the blood flow **(ω)** Blood flow measurements using our previously developed MEMS-LDF .There are many spikes caused by the movement of humans, such as flapping and picking. A closer look at the data reveals that all output signals are in the positive direction. This is because Doppler shifting measures the relative movement between the sensor and the skin, and there are no directional signals. Higher blood flow values possess lower reliability because they are interrupted by spike noise. In contrast, lower blood flow values are stable. Therefore, the sensor is designed to obtain stable blood flow data from a minimum value obtained over a small time segment shows an example of spike elimination by picking the minimum value in a small segment. This blood flow signal is obtained when the sensor probe is pushed to the human's chest. As a result, the blood flow value rises accompanied by spike noise reveals that this calculation helps in obtaining a stable blood flow rate.

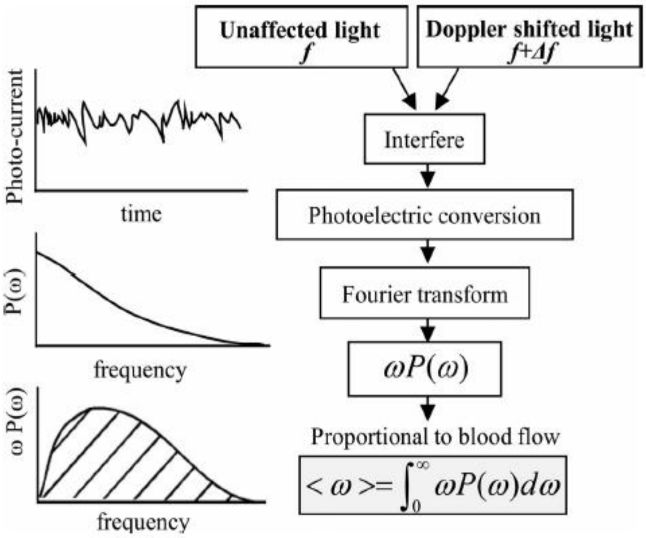


Fig 6 Process of calculation of the blood flow that occurs in the electric circuit box of the MEMS-LDF

Fig. 7 shows how the blood flow sensor allows the monitoring system to measure blood flow intermittently in order to lower power consumption compared with our previously developed blood flow sensor, because a sensor used for diagnostic purposes should be able to monitor blood flow over an extended period of time.

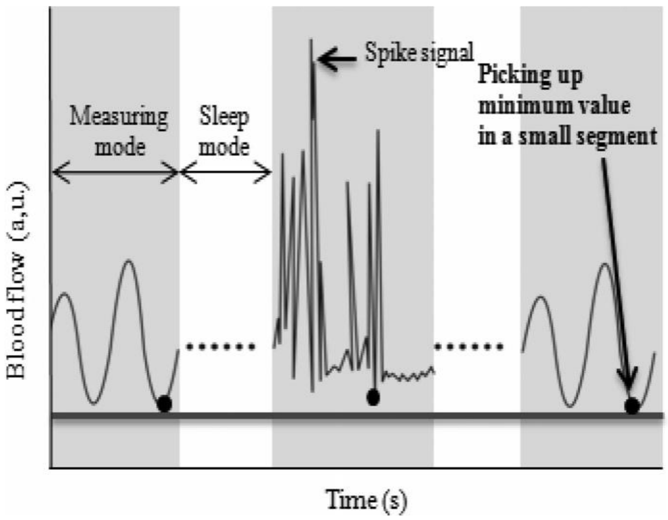


Fig7. Monitoring system of MEMS-LDF for humans introduced an intermittent measuring system to save power and obtain the minimum value in a small segment.

Therefore, the limited battery life of the sensor is conserved wherever possible. Intermittent measurement divides the gauging time into two modes: a measuring mode and a sleep mode. During sleep mode, the sensor is not engaged in monitoring blood flow, which permits low power consumption

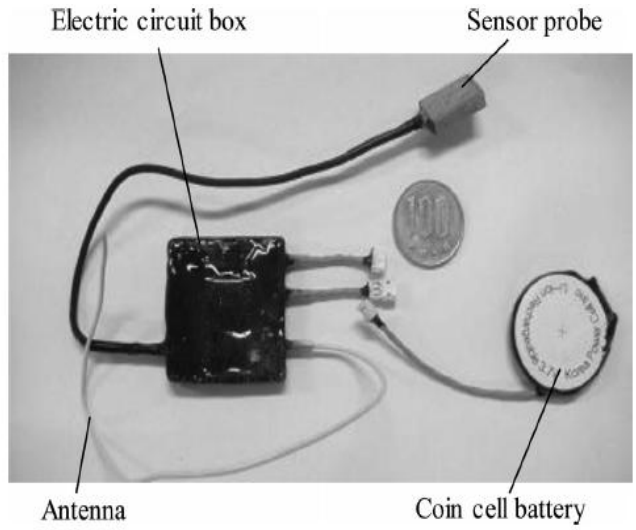


Fig 8: Actual design of human blood flow meter

Fig. 8 shows a **design of human blood flow meter** .The sensor probe size is very small and the electric circuit box includes the CPU and operational amplifier, and the transmitter (Zigbee) is and having very small weight. The sensor must be small and light to allow the human to perform normal activities equipped with a display and a plastic case. Because of the intermittent measurement system introduced in this device shows enhanced performance.

VI. Conclusion

We can develop an integrated laser Doppler blood flow micrometer to monitor blood flow in humans. The sensor weighs is very low and is wearable and wireless. These features enabled us to mount the sensor on humans and monitor their blood flow under normal conditions. The sensor system is designed to obtain only a small number of values over a small time period to minimize interruptions due to spike noise, and is able to provide stable and reliable blood flow data. Introduction of an intermittent measuring system made it possible for us to achieve low power consumption, enabling long-term measurement of blood flow.

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