

Optical fiber Hemoglobin concentration sensor based laser polarization

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Abstract

Optical fiber sensor for measuring hemoglobin concentration (Hb) of human peripheral blood depending on polarization is designed and implemented during this work. Its present a simple and accurate method to measure Hb concentration. Three lasers have been used in this system. These lasers are He-Ne laser with (632nm) wavelength, (5 mw) power, laser diode with (532nm) wavelength, (20 mw) power and another laser diode with(430nm) wavelength, (20 mw) power. biosensors use absorbance measurements to determine any changes in the concentration of analytes that absorb a given wavelength of light. The system works by transmitting light through an optical fiber to the sample; the amount of light absorbed by the analyte is detected through the same fiber or a second fiber.

Keywords: Optical fiber sensor, biomedical sensors, Hb concentration sensors, polarization based sensors

1-Introduction

The field of fiber optics has undergone tremendous growth and advancement over the last 25years. Initially conceived as a medium to carry light and images for medical endoscopic applications, optical fibers were later proposed in the mid 1960's as an adequate information carrying medium for telecommunication applications [1]. More recently, and especially since 1980, a great deal of research in optical fibers has been dedicated to sensing, and again the medical field found good opportunities for developing very promising sensors [2]. Optical –fiber biosensors offer several advantages over other biosensors : small size, flexible geometry, remote working capability, and noise immunity which make them ideal for clinical applications, environmental monitoring, and process control with easy operation.[3]. A novel method and instrumental system to determine the total protein concentration in a liquid sample is described by P.V. Preejith et.al [4] It uses a fiber optic total protein sensor (FOPS) based on the principles of fiber optic evanescent wave spectroscopy. The Hemoglobin (Hb) concentration in human blood is an important parameter to evaluate the physiological condition. A hemoglobin test reveals how much hemoglobin can be found in the blood. With this information anemia (a low hemoglobin level) and polycythemia vera (a high hemoglobin level) can be a diagnosed and monitored. It is also possible to observe imminent postoperative bleedings and autologous retransfusions. Currently, invasive methods are used to measure the Hb concentration. For this purpose blood is taken and analyzed. The disadvantage of this method is the delay between the blood collection and its analysis, which does not allow a real-time patient monitoring in critical situations. A non-invasive method allows pain free online patient monitoring with minimum risk of infection and facilitates real time data monitoring allowing immediate clinical reaction to the measured data is achieved by Mc.Grath et .al [5] . Compact fiber optical and thermal sensor for non invasive measurement of blood biochemistry including glucose, hemoglobin and it's derivatives concentrations is developed as a prototype of the point-of-care diagnostic devices for cardiologic, tumors and diabetic patients. Integrated platform for data acquisition, data processing and communication to remote networks has been developed on the pocket PC. Method of non-invasive monitoring of human blood biochemistry based on spatially localized NIR diffuse scattering spectroscopy and metabolic heat measurements has been developed. Multivariate statistical analysis and cluster analysis was applied to convert sensor pickup signals into physicochemical variables.[6]. In this work optical fiber biomedical sensor was designed and implemented for testing the hemoglobin (Hb). This system is based on light polarization technique.

Polarization technique to measuring Hb concentration

2-Experimental work

The set up of Polarization technique to measuring Hb concentration consist of: Light source (laser): Three lasers have been used in this system. These lasers are He-Ne laser with (632nm) wavelength, (5 mw) power, laser diode with (532nm) wavelength, (20 mw) power and another laser diode with(430nm) wavelength, (20 mw) power. These lasers have been selected because of the absorption spectrum of the hemoglobin (Hb) covers the wavelengths. Platform (optical bench): that is the fiber bench (FB-76W), Optical detector, Quarter wave plate ($\lambda/4$), Polarizer and Analyzer.

Figure 1 shows that the sample has been inserted between the quarter wave plate ($\lambda/4$) and analyzer. This could convert the output polarization of the light in to such plane (which is non circular polarization). By rotating the analyzer for getting the maximum intensity we can find how much the effect of sample on the polarization plane of the light.

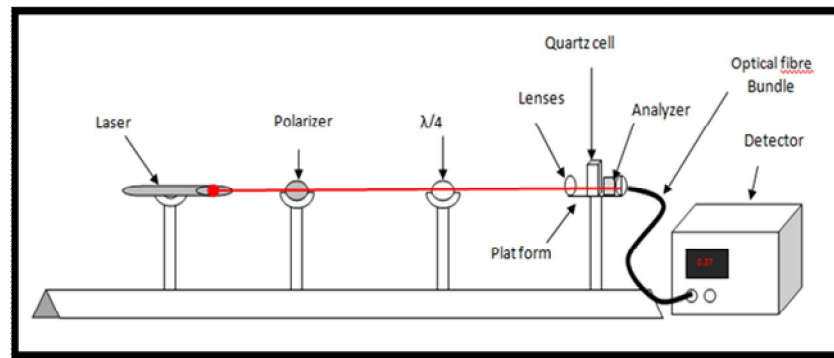


Figure 1 shows Experimental arrangement for bulk sample measurement using polarization technique to measure Hb concentration



Figure 2 the experimental setup photographic picture for the bulk sample measurement in polarization technique to measure Hb

3-Results and discussions:

Present study revealed the efficiency of using laser light at $\lambda=632\text{nm}$ after adding polarizer to the setup for sensing Hb rate achieved a significant light transmission (I/I_0) for women and men groups is 0.7725, 0.503333 respectively. In comparable to normal groups, are 0.6085, 0.957333 respectively as shown in figure (3). This results referred to highly sensitivity of red light with polarization feature to Hb percent, referred to anemic patients, this dependent on the quantity of absorbance light for each sample, where this device utilizes changes in molecular behavior induced carbon dioxide, concentration of bicarbonate ion and total carbon dioxide, acid-base balance, base excess, hemoglobin level, hematocrit, oxyhemoglobin level, deoxyhemoglobin level, and oxygen content can all be effected on the light transmitted after contact with this different molecules where each one absorbed part of light , which increase with increasing concentration of blood component. This result harmony with Mills, [7] described the device that determined blood contains. As well as, he described a device for immediate diagnosis of poisoning such as that due to carbon monoxide. It would be advantageous to allow rapid noninvasive screening of blood disorders such as sickle cell anemia.

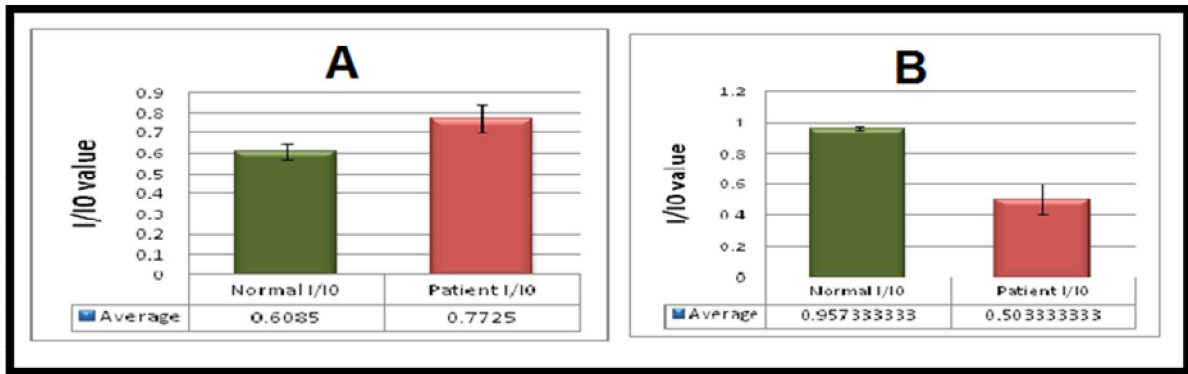


Figure 3 The light transmission of Hb, at ($\lambda=632\text{nm}$) depending on polarization for(A) Female and (B) Male. The polarization of $\lambda=532\text{nm}$ laser light, shows the low sensation for anemic women. It's give low ratio of I/I_0 was 0.612333 (Figure.4- A). Because of the ratio (I/I_0) for the men group is (0.603), there is no significant effect on this group. Figure (4- B). While this ratio is equal to 0.634333, 0.599333 for health women, and men respectively.

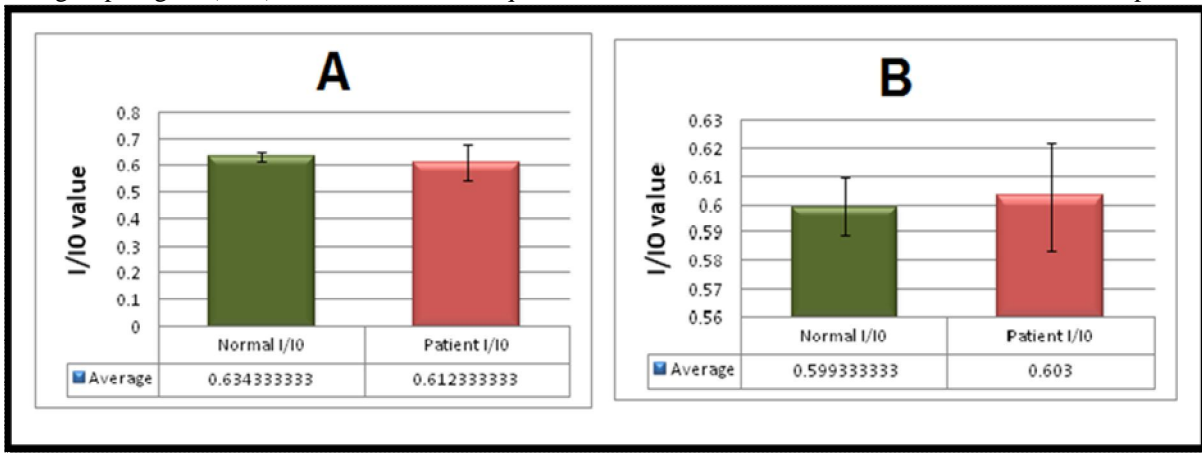


Figure 4 The light transmission of Hb, at ($\lambda=532\text{nm}$) depending on polarization for(A) Female and(B) Male.

The absorption coefficient (α) of Hb concentration for normal and patient female using polarized light as a function of the wavelength is shown in figure (5). The absorption coefficient (α) can be found by using beer-Lamberts law:

$$I/I_0 = e^{-\alpha x} \dots\dots\dots (1)$$

where I_0 is intensity of incident light, I is transmitted light, x is length of light path through solution α is specific absorption coefficient

.When the polarized light pass through the Hb concentrations, part of light has been absorbed, while another part will be passing and detected by photo detector.

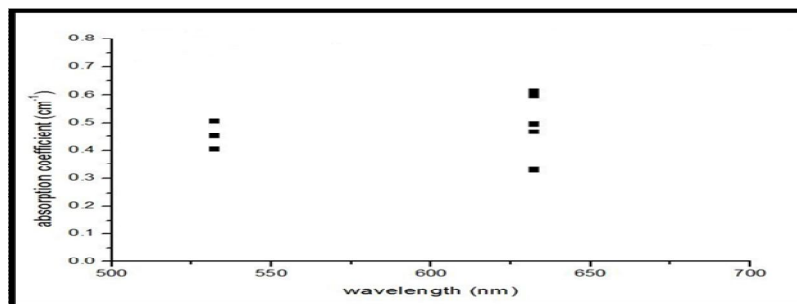


Figure 5 The relation between absorption coefficient (α) and the wavelength for normal female using polarized light.

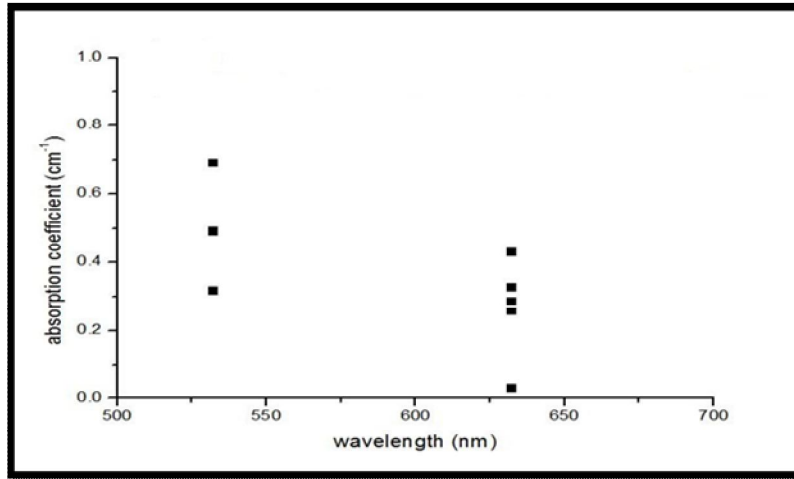


Figure 6 The relation between absorption coefficient (α) and the wavelength for patient female using polarized light.

Figures (5)-(6) shows that the absorption coefficient (α) of Hb was increased with increasing of the wavelength in normal female, while Hb absorption coefficient α decreased with increasing of the wavelength in anemic female. Table (1) shows the absorption coefficient (α) mean for normal and patient female when polarized light is used.

Table 1: absorption coefficient (α) mean for normal and patient female using polarized light.

| Wavelength(nm) | α (cm^{-1}) for normal female | α (cm^{-1}) for patient female |
|----------------|---|--|
| 532 | 0.455819 | 0.499188 |
| 632 | 0.502088 | 0.26711 |

From table 1 the difference between normal and patient female by using polarization technique at 632nm wavelength. Figure (5) explain that the absorption coefficient (α) increased with decreasing the wavelength. at α behavior of Hb for normal male when polarized light is used at (532nm and 632nm).

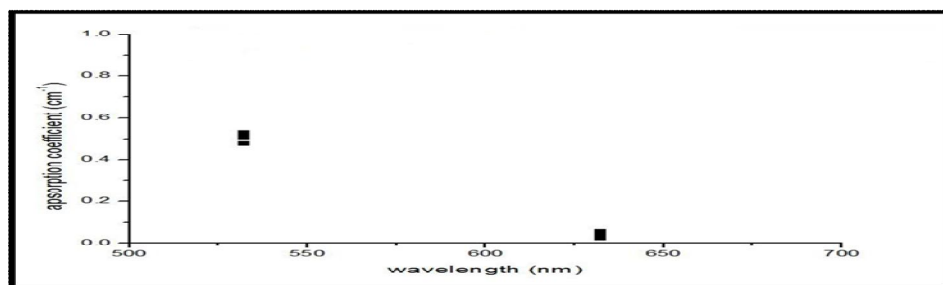
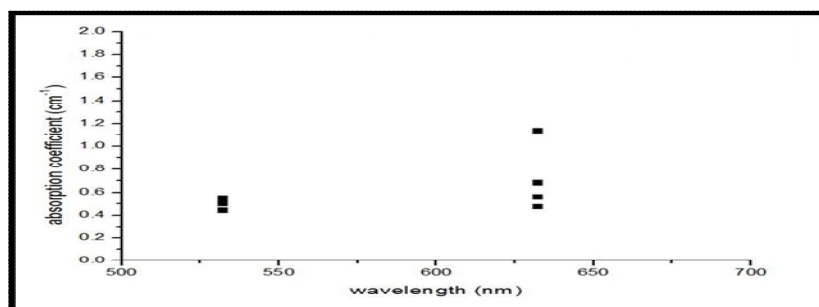


Figure 7 the relation between absorption coefficient (α) and the wavelength for normal male using polarized light.



Figur8 the relation between absorption coefficient (α) and wavelength for patient male using polarized light.

Figure 8 Explain the relation between α of the Hb for patient male at (532nm and 632 nm) wavelength when polarized light is used.

The absorption coefficient of Hb for patient male increases with increasing wavelength.

Table (2) shows the absorption coefficient (α) mean for normal and patient male when we used polarization technique.

Table 2: absorption coefficient (α) mean for normal and patient male

| Wavelength(nm) | α (cm^{-1}) for normal male | α (cm^{-1}) for patient male |
|----------------|---|--|
| 532 | 0.512159 | 0.506597 |
| 632 | 0.043659 | 0.716523 |

Table (3) shows the difference between absorption coefficients (α) at (532 nm and 632 nm) wavelengths for normal female and male by using polarized technique.

Table 3: absorption coefficient (α) mean for normal female and normal male using polarized light.

| Wavelength(nm) | α (cm^{-1}) for normal female | α (cm^{-1}) for normal male |
|----------------|---|---|
| 532 | 0.455819 | 0.512159 |
| 632 | 0.502088 | 0.043659 |

Table (4) shows difference between absorption coefficients (α) for patient female and male by using polarized light at (532nm and 632nm) wavelengths.

Table 4: absorption coefficient (α) mean for patient female and patient male using polarized light.

| Wavelength(nm) | α (cm^{-1}) for patient female | α (cm^{-1}) for patient male |
|----------------|--|--|
| 532 | 0.499188 | 0.506597 |
| 632 | 0.26711 | 0.716523 |

Tables (3 and 4) show difference of mean absorption coefficient between (men and women) at normal groups. The absorption coefficient mean is increases with increasing of wavelength in women group, while in men group the mean of the absorption coefficient deceases with the wavelength. While in patients group this mean was inversed, the absorption coefficient mean of women group decreases by decreasing of wavelength, while in men group the absorption coefficient mean increases with increasing of wavelength. This result is due the rotation of polarization of the transmitted beam by the sample.

We conclude that the red light was more sensitive for Hb quantity in the anemic patients with highly significant from other lights. Recent study reveals the efficiency of using laser light at $\lambda=632\text{nm}$ wavelength after adding polarizer to the setup for sensing to Hb rate achieved a significant light transmission (I/I_0) for women and men groups. The study, proves that the $\lambda=410\text{nm}$, doesn't have any effect in diagnosis anemic cases, where the average of light transmission is around zero.

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