Effect of Diabetes in Blood Dilution and Angle of Rotation on the Output Power of Second Harmonic Generation of Nd: YAG Laser

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Abstract

Glucose monitoring is a crucial factor for diabetic self management. Widely used technologies require the use of fresh blood samples in special test strips. This is expensive and does not lend it self to continuous monitoring. An alternative method of measuring blood glucose levels optically is investigated. This method is called "Optical Activity". It's able to determine glucose concentrations with varying degrees of sensitivity and ranges of applicability. This method is used to determine the angle of rotation for different glucose concentrations when the laser beam passing through the samples of blood.

In this research, a green laser of second harmonic generation (SHG) of Nd: YAG with measured maximum output power 55 mW and wavelength of 532 nm was used. The output power of laser beam which was passing through the glass cuvette of blood with diabetes was measured as a function of calculated specific rotation angle for different concentrations of the diluted blood and also the output power of laser beam which was passing through the glass cuvette of blood with null diabetes was measured. These results of two samples are reported and the implications for possible new monitoring strategy are considered. Thus, the person can be specified his blood contain the diabetes or not.

Keywords: Diabetes, Glucose, Diluted blood, Second Harmonic Generation (SHG) of Nd: YAG Laser, Optical Activity, and Angle of rotation.

Introduction

Diabetes mellitus is a medical condition in which the body does not adequately produce the quantity or quality of insulin needed to maintain a normal circulating blood glucose. Insulin is a hormone produced by the pancreas, a large gland behind the stomach, that enables glucose (sugar) to enter the body's cells to be used for energy [1].

At eating, the pancreas automatically produces the right amount of insulin to move glucose from blood into our cells. In people with diabetes, the pancreas either produces little or no insulin, or the cells do not respond appropriately to the insulin that is produced. Glucose builds up in the blood, overflows into the urine, and passes out of the body in the urine. Thus, the body loses its main source of fuel even though the blood contains large amounts of glucose.

Three main types of diabetes are: Insulin Dependent Diabetes Mellitus (IDDM), Non-Insulin Dependent Diabetes Mellitus (NIDDM), and Gestational Diabetes [2, 3].

An estimated 20.8 million people in the United States-7.0 percent of the population-have diabetes, a serious, lifelong condition. Of those, 14.6 million have been diagnosed, and 6.2 million have not yet been diagnosed. In 2005, about 1.5 million people aged 20 or older were diagnosed with diabetes as shown in Fig.(1) [2].

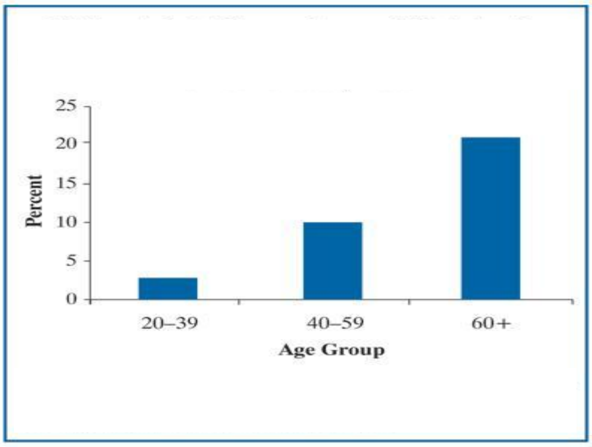

Fig.(1) Estimated total prevalence of diabetes in people aged 20 years or older by age group United States,2005 [2].

The optical activity method is based on the rotation of linearly polarized light as it travels through certain materials. It occurs in solutions of chiral molecules such as sucrose which is being developed as a method to measure blood sugar concentration in diabetic people [4].

Optical Activity

All old methods are used in laboratory take long time and its need to spate the serum from the human blood to measure the diabetes in blood. Therefore, there is a new method which its use the blood without separated the components of it. This method is cheap, easy and take short time to known that sample of blood contains the diabetes. This method is called optical activity. It is explained as fellow: When polarized light is passed through optical isomers (stereoisomers that can be formed around asymmetric carbons) the direction of the light is changed. Optical isomers often have two isomers that are the same in every way except that they are non-super imposable mirror images of each other. These are called chiral molecules. The change of direction of the polarized light passing through these molecules is called optical activity. The degree of rotation depends on the wavelength of the light, the optical path length, the specific rotation, characteristics of the material, and the concentration of the material [4].

The observed rotation is dependent upon the path length of the light passing through the glass cuvette and the number of molecules of glucose. The observed rotation is converted to a specific rotation by using the following formula [5, 6]:

$$\theta' = \theta / L * C \quad ....(1)$$

where:

θ' is the specific rotation angle,

θ is the observed rotation angle in degree,

L is the length of sample tube (decimeters),

C is the concentrations of blood dilution (g/ml).

Experimental Work and Results

To test for the optical activity of glucose in blood with diabetes and with null diabetes, an experimental arrangement of simple polarimerter in figures 2a and 2b were built as follows :

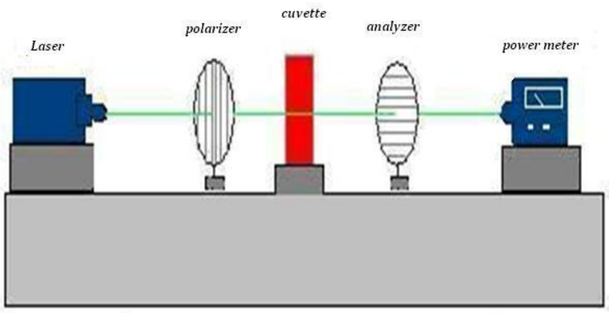

Fig.(2a) Simple polarimeter arrangement.

Fig.(2b) Experimental set up.

1. Setup are constructed from second harmonic generation (SHG) Nd:YAG laser of 532nm and measured output power of 55mW as a light source, polarizer, squared glass cuvette with interior dimensions of 10×10×35mm and thickness of 25μm as the blood container, and a powermeter. The analyzer is oriented 90° to the polarizer so that no light reaches the powermeter. When an optically active substance (blood with diabetes) is present, it rotates the polarization of the light reaching the analyzer so that there is a component that reaches the powermeter. While the blood with null diabetes cannot rotates the polarization of the light, so the rotation angle of blood with null diabetes is zero.
2. At the beginning of the work, a spectro-photometer of range 200nm-1200nm (UV/VIS METERTECH SP8001) was used to measure the absorption coefficients of

both null blood and blood with diabetes. Its absorption coefficients were measured for different values of wavelengths. Results are shown in Fig.(3) and Table (1).

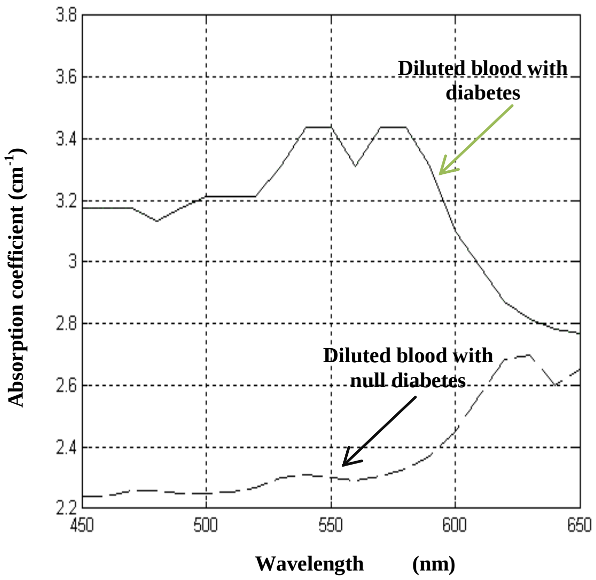

Fig.(3) The absorption coefficients of blood with null diabetes and blood with diabetes against wavelengths.

Table (1)
The result of the absorption coefficients of both blood with null diabetes and blood with diabetes as a function of wavelengths.

Wavelength λ (nm)	***Absorption Coefficients (cm^{-1})***	
	Blood with null diabetes	***Blood with diabetes***
٤٥٠	٢.٢٤١٣	٣.١٧٤٩
٤٦٠	٢.٢٤١٣	٣.١٧٤٩
٤٧٠	٢.٢٦٠١	٣.١٧٤٩
٤٨٠	٢.٢٦٠١	٣.١٣٥١
٤٩٠	٢.٢٥٠٧	٣.١٧٤٩
٥٠٠	٢.٢٥٠٧	٣.٢١٤٨
٥١٠	٢.٢٥٥٤	٣.٢١٤٨
٥٢٠	٢.٢٧٠٠	٣.٢١٤٨
٥٣٠	٢.٣٠١٠	٣.٣١١٣
٥٤٠	٢.٣١١٨	٣.٤٣٦٢
٥٥٠	٢.٣٠١٠	٣.٤٣٦٢
٥٦٠	٢.٢٩٠٤	٣.٣١١٣
٥٧٠	٢.٣٠٦٤	٣.٤٣٦٢
٥٨٠	٢.٣٢٨٤	٣.٤٣٦٢
٥٩٠	٢.٣٦٩٩	٣.٣١١٣
٦٠٠	٢.٤٥٠٧	٣.١٠١٤
٦١٠	٢.٥٧١٠	٢.٩٨٥٠
٦٢٠	٢.٦٨٣٣	٢.٨٧٢١
٦٣٠	٢.٧٥٤٢	٢.٨١٦٧
٦٤٠	٢.٦١١٤	٢.٧٨٣٠
٦٥٠	٢.٦٥٣٠	٢.٧٦٦٨

3. With the aid of powermeter device, the transmitted power of laser beam before and after the analyzer can be measured. Different readings for two different samples of blood were taken for each concentrations of blood dilution.
4. The laser beam cannot pass through the glass cuvette of blood with null diabetes because of it is dense. Therefore, it is diluted with distilled water. So, the transmit power of laser beam which was passing through the glass cuvette of blood with null diabetes was measured. Also, the transmitted power of laser beam which was passing through sample of blood with diabetes was measured. The natural glucose levels in blood are typically between 0.7206 mg/ml and 1.0809 mg/ml. Fasting levels above 1.0809 mg/ml are found in individuals who are insulin resistant and levels above 1.261 mg/ml are typical of diabetes [7]. Therefore, the case of glucose concentration levels above 1.261 mg/ml would suffer of diabetes in blood. This level of 1.261 mg/ml was considered in our calculations. Results for two samples of bloods are shown in Fig.(4) and Table (2).

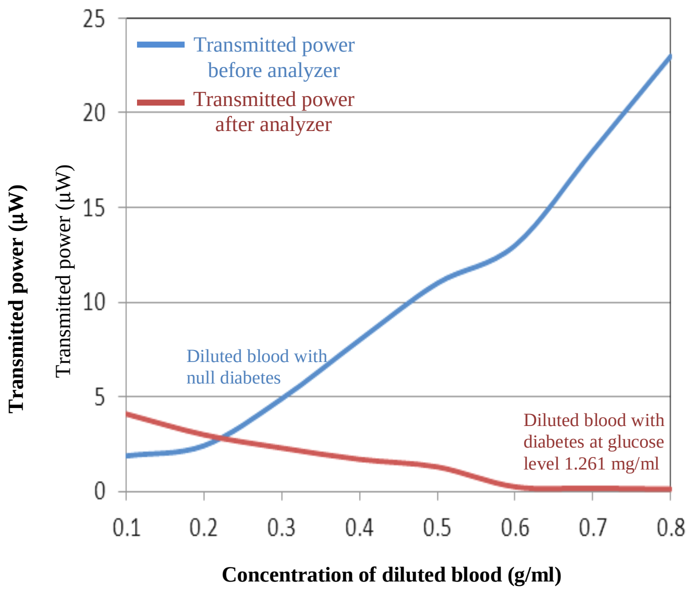

Fig.(4) Transmitted power against the concentrations of diluted blood with null diabetes and blood with diabetes.

Table (2)
The result of the transmit power of laser for different concentrations of diluted blood with null diabetes and blood with diabetes.

Concentration of diluted blood (g/ml)	*Transmit Power(μw)*	
	Blood with null diabetes	*Blood with diabetes at glucose level 1.261 mg/ml*
0.1	١.٨٨	4.1
0.2	٢.٤٢	3
0.٣	٤.٩	2.3
0.٤	٨	1.7
0.٥	١١	1.3
0.٦	١٣	0.25
0.٧	١٨	0.18
0.٨	٢٣	0.125

In Fig.(4) the transmitted power of laser beam was measured when it passing through glass cuvette contains blood with diabetes which is less than the transmitted power of laser that was passing through glass cuvette contains blood with null diabetes, because of the concentrations of the glucose in the diluted blood with diabetes is greater than in the diluted blood with null diabetes. High glucose concentration in blood lead to absorption of more power from the laser beam due to form the stereoisomers.

5. The transmit power after the analyzer was change because of the concentration of sample would changed. Therefore the analyzer must be rotated until the power reached powermeter. The observed rotation angle (analyzer angle) for different concentration of diluted blood with diabetes was measured as shown in Fig.(5) and Table (3).

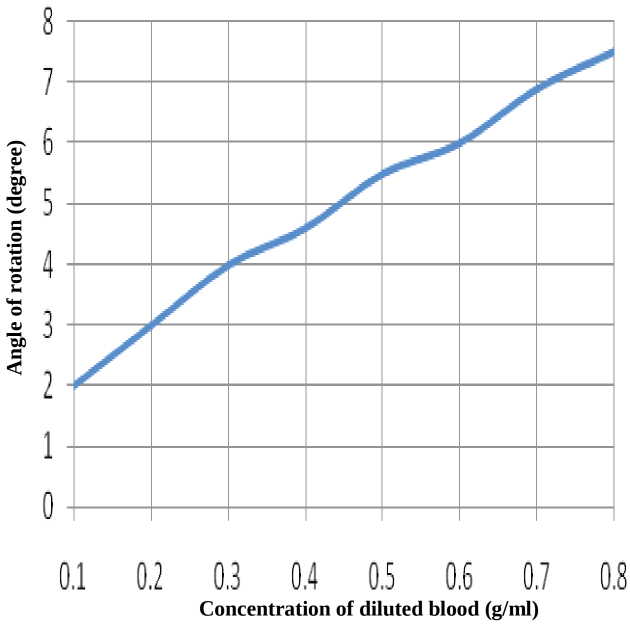

Fig.(5) The measured rotation angle against the concentrations of diluted blood with diabetes.

Table (3)
The result of the angle of rotation for the different concentrations of diluted blood with diabetes.

Angle of rotation(deg.)	*Concentrations of diluted blood (g/ml)*
2	0.1
3	0.2
4	0.3
4.6	0.٤
5.5	0.٥
٦	0.٦
6.9	0.٧
7.5	0.٨

6. The specific angle of rotation of the diluted blood with diabetes for different concentr-ations of diluted blood were calculated using (eq.1).The transmit power of laser beam which was passing through the glass cuvette of blood with diabetes was measured as a function of calculated specific rotation angle for different concentrations of the diluted blood. Results are shown in Figs. (6 and 7) and Table (4).

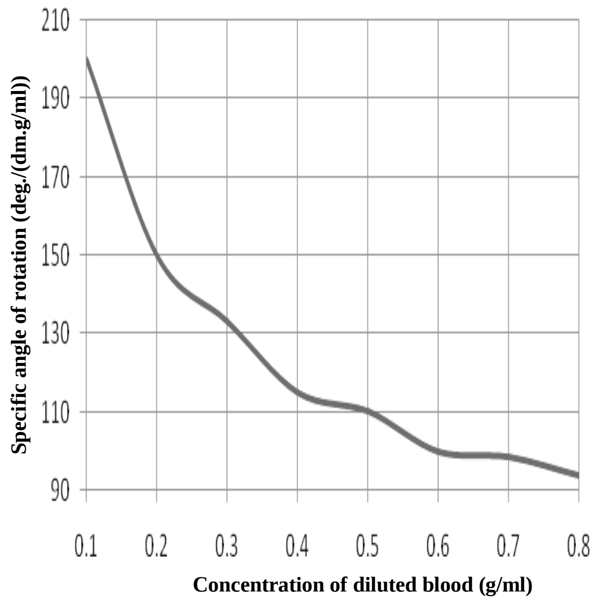

Fig.(6) The specific angle of rotation against the concentrations of diluted blood with diabetes.

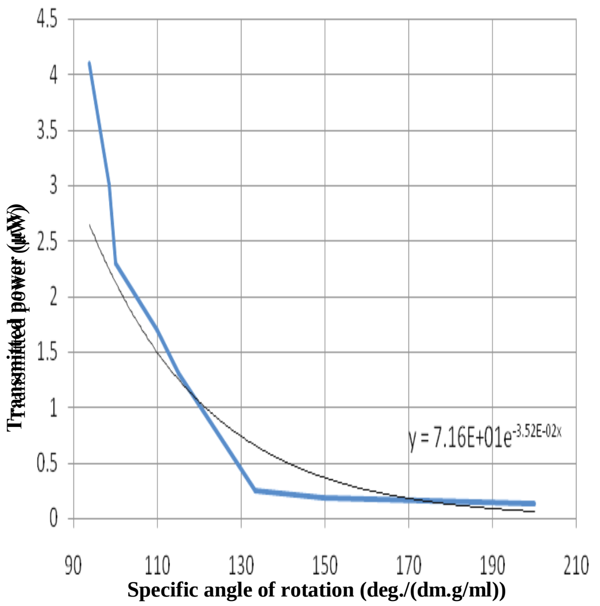

Fig.(7) Transmits power against the specific angle of rotation.

In Fig.(7), the relationship between the transmit power of laser beam and the specific angle of rotation could be described by an empirical equation which it's given by:

$y = 71.6\ e^{-0.0352\ X}$

where

y is the transmit power of laser beam, and

x is the specific angle of rotation.

Table (4)
The result of the transmit power and specific angle of rotation for the concentrations of diluted blood with diabetes.

Transmit power (µw)	*Specific angle of rotation (deg./(dm.g/ml))*	*Concentrations of diluted blood (g/ml)*
0.125	200	0.1
0.18	150	0.2
0.25	133.3	0.3
١.٣	115	0.4
١.٧	110	0.5
٢.٣	100	0.6
٣	98.57	0.7
٤.١	93.75	0.8

Conclusions

1- Diluted blood with diabetes will suffer from higher absorption coefficients compared with the diluted blood with null diabetes, spatially at wavelength range from 525nm to 550nm. This increment in the absorption coefficient is due to the increase the glucose concentrations in diluted blood.

2- At the beginning, in diluted blood with null diabetes, the angle of rotation would equal to zero because of the direction of the polarized light is not changed due to chiral molecules which its caused to change the rotation angle of diluted blood with diabetes.

3- The optical activity method represents an important step toward the development of a noninvasive glucose sensor that may eventually be capable of detecting diabetes in the human blood.

4- The advantages of method in this work, is easy in design, cheap in price, and taken short time to decide the human blood contained diabetes or not by monitoring the change of rotation angle with the concentrations of diluted blood.

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الخلاصة

مراقبة الكلوكوزِ عامل حاسم للإدارةِ الشخصية لداء السكر. تَتطلّبُ التقانات الحالية الشائعة الإستعمالُ أستخدامُ عيناتِ دمّ جديدةِ في أشرطةِ الإختبار الخاصّةِ وهي غاليةُ وغير ملائمة للمراقبة المستمرةِ .هنالك طريقة بديلة لكشف مستويات كلوكوزِ الدمِّ بصرياً وهذه الطريقةِ تُدْعَى "النشاط بصري". تَتطلّبُ هذه الطريقةِ حسابَ زوايا الدورانِ لعدة تراكيزللدمِّ المخفف عندما يمر مصدرَ ضوء مستقطبَ من خلالِ عيّنةِ الاختبار.

في هذا البحث أستخدم ليزر ذو اللون الأخضر الناتج من التوافقية الثنائية لليزر النديميوم–ياك ذو قدرة خرج بحدود ٥٥ mW وطول موجي nm٥٣٢ ،وتم قياس قدرة الليزر النافذة كدالة لزاوية الدوران من خلال مروره بعينة من الدم المخفف التي تحتوي على نسبة عالية من السكر وكذلك قياس قدرة اليزر النافذة من خلال مرورها بعينة من الدم المخفف التي تحتوي على النسبة الطبيعية للسكر وأجراء مقارنة بين الحالتين. النتائج التي حصلنا عليها في هذا البحث فتحت افاق جديدة لمراقبة السكر في الدم بحيث أنه من خلال مراقبة زوايا الدوران لعينة الدم يمكن للشخص أن يحدد بأنه مصاب بداء السكري أو لا.