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Laser Irradiation Effects on The Optical Properties of (Normal and Abnormal) Human Blood Samples

A Thesis

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By

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(اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ (١) خَلَقَ الْإِنسَانَ مِنْ عَلَقٍ (٢) اقْرَأْ وَرَبُّكَ الْأَكْرَمُ (٣) الَّذِي عَلَّمَ بِالْقَلَمِ (٤) عَلَّمَ الْإِنسَانَ مَا لَمْ يَعْلَمْ (٥))

صدق الله العلي العظيم

سورة العلق

Dedication

TO my wealth in this world and with their support , I reached here

(My father and My mother) .....

To those who are part of my soul and my backbone

(Reyam, Ali, Sadiq) .....

To my soul mate, to the painting of tenderness that painted from flowers

(Lubna) .....

Raneem

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Praise, thanks and gratitude to God Almighty ,I would like to extend my highest appreciation and respect to my supervisors (Prof.Dr. Wajehaa abd Al-Daim , and Asst.Prof.Dr. Sadiq Hassan), for their valuable contribution in the research.

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Raneem Mohammed Abbas

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جامعة بابل

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تأثيرات اشعاع الليزر على الخواص البصرية لعينات دم الانسان (الطبيعية و غير الطبيعية)

اطروحة مقدمة الى

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الخلاصة:

ظهر اهتمام كبير و متزايد في البحوث العلمية و التقنية لدراسة استخدام اشعة الليزر في مجالات مختلفة ، في دراستنا الحالية تم تناول شقين لدراسة تأثير اشعة الليزرعلى نسيج الدم منها الشق العملي و الذي من خلالة تم دراسة تأثير أشعة الليزر على الخواص البصرية لنسيج الدم السليم و المصاب بفقر الدم بالاضافة الى الدم المصاب بالثلاسيميا ، و كذلك دراسة تأثيره على بلازما الدم السليم من خلال التغييرات الحاصلة في الخواص البصرية. اما الشق الاخر تضمن نظام محاكاة لدراسة تأثير الحرارة المتولدة خلال نسيج الدم اثناء عملية التشعيع بواسطة معادلة (Bioheat equation) .

تضمنت هذه الاطروحة ، دراسة واسعة لبعض الخواص البصرية لعينات الدم البشري السليم و المصاب بفقر الدم و كذلك الثلاسيميا في ظروف مختبرية قياسية ، فقد تم جمع (27) عينة من متبرعين اطفال و نساء تتراوح اعمارهم بين (12-30) سنة ، حيث قسمت الى ثلاثة مجاميع كل مجموعة تتألف من (9) عينات من دم المتبرعين السليمين ، (9) عينات لمتبرعين مصابين بفقر الدم ، و (9) عينات لمتبرعين مصابين بالثلاسيميا مع الاحتفاظ بعينة سيطره لكل مجموعة ، بالاضافة الى مجموعة بلازما الدم السليم مع الاحتفاظ بعينة سيطرة ايضا.

عرضت عينات المجاميع الاربعة (الدم السليم ، الدم المصاب بفقر الدم ، الدم المصاب بالثلاسيميا ، و بلازما الدم السليم) الى التشعيع بأشعة الليزرالمستمرة بواسطة ليزرات الحالة الصلبة و ليزرات اشباه الموصلات و لأربعة اطوال موجية (405nm , 473 nm , 532 nm , 650 nm) و بقدرة خرج (20mW) و بفترات زمنية مختلفة (5 min,10 min) .

اشتملت الدراسة الحالية على دراسة و تحليل الخواص البصرية للعينات و قياس بعض المعلمات البصرية منها (الامتصاصية ، النفاذية) ،و الثوابت البصرية(معامل الامتصاص الخطي ، معامل الاضمحلال ، بالاضافة الى التوصيلية البصرية) بواسطة جهاز المطياف ذو الحزمة المزدوجة (Double-Beam Spectrophotometer) في منطقتي الاشعة فوق البنفسجية و الضوء المرئي (Uv-Vis) عند مدى الاطوال الموجية يمتد بين (190nm-1100nm) ضمن الطيف الكهرومغناطيسي.

بينت نتائج دراسة الخواص البصرية لعينات الدم السليم بعد التشعيع بمختلف الاطوال الموجية وجود تغيير في قيمها ، حيث ازدادت قيمة الامتصاصية عند زيادة زمن التعرض (10 min) و بلغت اقل قيمة للامتصاصية عند التشعيع بزمن تعرض (5 min) ، كما هو الحال في عينات الدم المصابه بفقر الدم و الثلاسيميا ، حيث ازدادت ايضا قيم الامتصاصية بعد التشعيع و عند زمن تعرض (10 min) مع تغيير باقي قيم الخواص البصرية عند مقارنتها بقيم الخواص البصرية التابعة لعينات السيطرة (العينات قبل التشعيع) .

ايضا اشتملت الدراسة على توضيح تأثير التشعيع بالليزر على (بلازما الدم السليم) من خلال دراسة الخواص البصرية لعينات بلازما الدم السليم قبل التشعيع و بعد التشعيع بالاطوال الموجية الليزرية المختلفة (405nm,473nm,532nm,650nm) ، ومن خلال النتائج وجد بأن بلازما الدم السليم تكون ضعيفة الامتصاص الى الاطوال الموجية القصيرة نتيجة لعدم زيادة الامتصاصية بعد التشعيع بشكل كافٍ اما في حالة استخدام الاطوال الموجية الاطول فقد اظهرت النتائج زيادة واضحة في الامتصاصية بعد عملية التشعيع و هذا يعني ان البلازما تكون ذات امتصاصية اقوى عند الاطوال الموجية الاطول .

تناول الشق الثاني من الدراسة نظام محاكاة بواسطة (COMSOL Multiphasic) لدراسة التأثير الحراري لأشعة الليزر المتولدة داخل العينة بأختلاف ازمان التعرض و قد اظهرت النتائج بأن التأثير الحراري يزداد بزيادة زمن التعرض لاشعة الليزر و بالتالي زيادة في عمق الاختراق لاشعة الليزر داخل العينة اثناء عملية التشعيع و بالتالي انتشار للحرارة المتولدة داخل العينة من مركز التشعيع بأتجاه جدران العينه .

Abstract:

There has been a great and growing interest in scientific and technical research to study the use of laser beams in various fields. In the current study , two parts were taken to study the effect of laser radiation on blood tissue , including the practical part , the effect of laser radiation was studied on the optical properties of healthy and anemic blood tissue in addition to blood with thalassemia , as well as studying its effect on health blood plasma through changes in optical properties. The other part, it included a simulation system to study the effect of heat generated through the blood tissue during the irradiation process by using a (Bioheat equation).

This thesis included a broad study of some optical properties of healthy and anemic human blood samples, as well as thalassemia, under standard laboratory conditions , (27) samples were collected from children and women donors , their ages ranged between (12-30) years , divided into three groups , each group consisting of (9) samples of blood from healthy donors, (9) samples from donors suffering from anemia, and (9) samples from donors with thalassemia with keeping a control sample for each group, in addition to the healthy blood plasma group while keeping a control sample as well. The samples of the four groups (normal blood, anemic blood, thalassemia blood, and healthy blood plasma) were exposed to continuous laser irradiation by solid-state and semiconductor lasers of four wavelengths (405 nm, 473 nm, 532 nm, 650 nm) and with an output power (20mW) and with different exposure times (5min,10min).

The current study included studying and analyzing the optical properties of the samples and measuring some optical properties including (absorption,

transmittance), and optical constants (linear absorption coefficient, extinction coefficient, in addition to optical conductivity) by (Double-Beam Spectrophotometer) device in the ultraviolet and visible light (Uv-Vis) regions at the wavelength range extending between (190nm-1100nm) within the electromagnetic spectrum. The results of studying the optical properties of healthy blood samples after irradiation at various wavelengths showed a change in their values, as the absorbance value increased when the exposure time at (10 min), and the lowest value of the absorbance was reached when irradiated with an exposure time (5 min), this is also what was obtained with blood samples that suffer from anemia and thalassemia, where the absorbance values also increased after irradiation and at exposure time (10 min) with changing the other optical properties values when compared with the optical properties values of the control samples (samples before irradiation). The study also included an illustration of the effect of laser irradiation on (healthy blood plasma) by studying the optical properties of healthy blood plasma samples before and after irradiation at different laser wavelengths (405nm, 473nm, 532nm, 650nm), and through the results it was found that healthy blood plasma is poorly absorbed to short wavelengths as a result of not sufficiently increasing the absorbance after irradiation. In the case of using longer wavelengths, the results showed a clear increase in absorbance after the irradiation process. This means that the plasma has a stronger absorbance at longer wavelengths. The second part of the study dealt with a simulation program by (COMSOL Multiphasic) to study the thermal effect of the laser beams generated inside the sample with different exposure times. The results showed that the thermal effect increases with the increase in the time of exposure to the laser beams, and thus an increase in the penetration depth of the laser beams inside the sample during the irradiation process, and consequently the spread of the heat generated inside the sample from the center of the Irradiation towards the walls of the sample container.

(List of Contents)

Chapter Four
Results and Dissection
Part One : Experimental part

(List of Symbols and Abbreviation)

Symbols , Abbreviation	*Description*
DPSSL	Diode-Pumped Solid State Laser
EDTA	Ethylene Diamine Tera Acetic Acid
WBC	White Blood Cell
RBC	Red Blood Cell
CW	Continuous Wave
Uv	Ultraviolet
LED	Light Emitting Diode
He-Ne	Helium-Neon laser
PRP	Platelet-rich plasma
$\mathbf{TEM_{00}}$	Transverse single mode
A	Absorbance
T	Transmittance
$\mathbf{I_o}$	Incident intensity
$\mathbf{I_1}$	Transmitted intensity
$\boldsymbol{\lambda}$	Wavelength
$\boldsymbol{\alpha}$	Absorption coefficient
k	Extinction coefficient
ℓ	Distance of light passed through material
$\boldsymbol{\rho}$	Density
c	Specific heat
$\boldsymbol{k}$	Thermal conductivity
t , b	Tissue and Blood domain
T	Temperature

$\mathbf{q_m}$	Heat generations due to metabolism
$\mathbf{W_b}$	Blood perfusion rate
$\mathbf{T_a}$	Arterial blood temperature
N	Complex refractive index
n	Refractive index
$\boldsymbol{\sigma_{opt.}}$	Optical conductivity

Chapter One

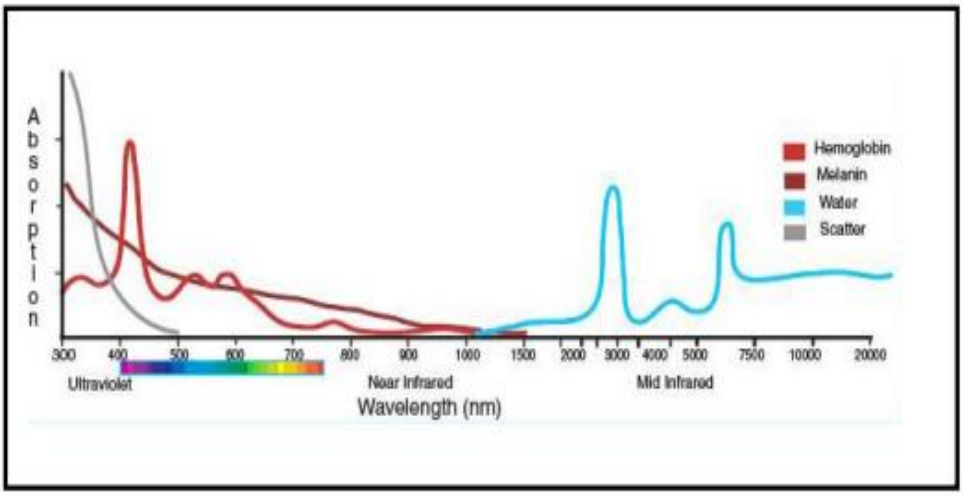
General Introduction

(1-1)Introduction:

After the invention of the system of laser, several researches were performed investigation potential interaction on tissue by means that of every kind of lasers and biological tissues [1] , whereas the amount of possible composition for the experimental parameters is unlimited, primarily five types of interaction are classified. These are: chemistry interactions, thermal interactions, ablative photodecomposition, plasma-mediated ablation, and photo- disruption [2]. Before concentrating on those interactions , it will demonstrate the importance of study the optical properties for living tissues [3]. The importance due to the adoption of light penetration in the living tissues on laser parameters and optical properties of tissues. Therefore, every biological tissue has individual class response functions once irradiated by laser system [4]. The main phenomena happening when living tissue is irradiated by laser light resulting from diffusion of light in tissue , and these phenomena are : reflection, scattering, absorption and fluorescence. Reflection can be stultified by law of Fresnel [5]. The penetration of laser light inside living tissue lean on optical properties of living tissue, such as refractive index , scattering , and likewise absorption of laser light by living tissue [6] . The depth of penetration for the beam of laser depends on many parameter of laser (wavelength , power , duration , time of exposure, spot size) and on color and consistency of the tissue.

Each tissue has specific absorption characteristics base on its composition and chromophore content. The principal chromophores tissue are: (Hemoglobin , Melanin , Water , Protein) [7].

Infrared light is absorbed primarily by water, while visible and ultraviolet light are primarily absorbed by hemoglobin and melanin, respectively [8]. As wavelength decreases toward the violet and ultraviolet, scatter or absorption from covalent bands in protein limits penetration depth in the range , Figure (1-1) [8] .



Figure(1-1): Absorption of the Main Chromophore [8]

When the laser beam orientation occurs towards the tissue, the direct reflection is only approximately 3% of the incident light, either the remaining light goes into the tissue, or suffers from absorption and dispersion, and the rate of heat generation depends on the rate of absorption of photons within the tissues. The scattered light absorbed may cause heat outside the laser beam [9] , Figure(1-2) .

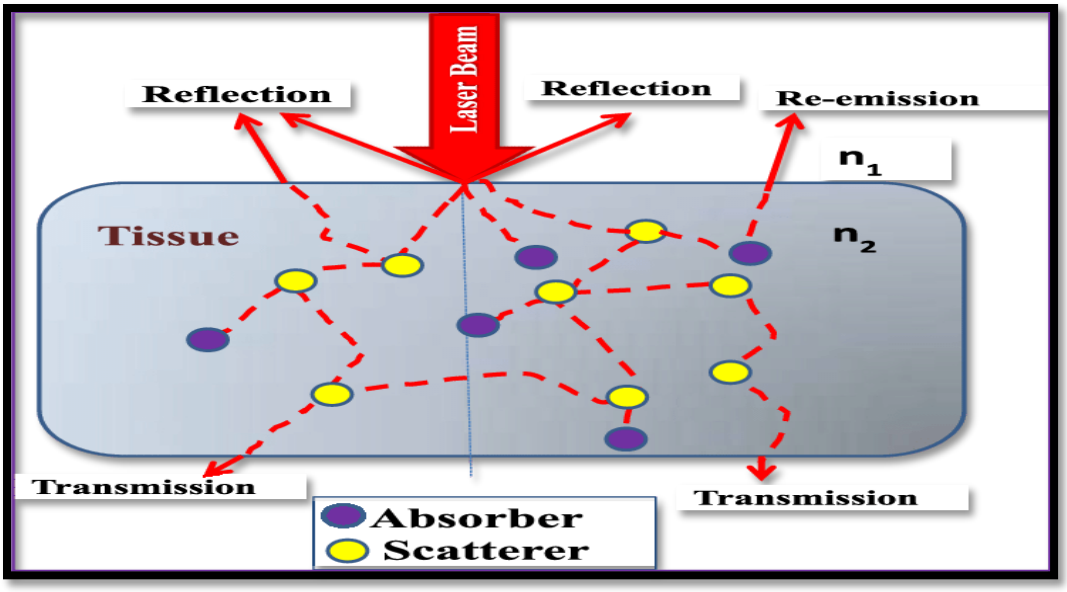


Figure (1-2) : The interaction between laser light and living tissue[10]

The energy range emitted by the laser beam can be used for medical applications in cutting or welding, as it causes cell necrosis and tissue clotting. This ability can be widely used in surgical procedures and correction of the corneal refractive index.

There are two groups of lasers that are commonly used in medical fields and that consist of: -

1. Lasers with low therapeutic energy: This type is used to stimulate cell functions. Biological effects are not thermal, as is the case when used with laser surgery, since therapeutic lasers are generally defined as a laser that uses energy densities less than the threshold limit energy where it can be there are adverse effects in the activities of the cell.

2. High-power laser (heating): This type can be used in surgical procedures, which causes cutting, clotting, and necrosis of tissues, and these lasers are often called surgical lasers because they are used in surgery instead of a scalpel [11].

There are two models for interactions between laser and living tissues : (thermal and non-thermal). Thermal mechanisms include vaporization and photo-coagulation . Non-thermal mechanisms are photo ablation and photo-dry-etching of tissues [12] . Thermal damage has a degree dependent on the temperature to which the laser energy heats the tissue. Table 1.1 shows the changes that occur as the laser beam is absorbed [8].

Table 1.1: Tissue Changes with Temperature Increases [8]

Temperature	Biological change
37-60° C	Warming , welding
60-65° C	Coagulation
65-90° C	Protein denaturization
90-100° C	Drying
100° C	Vaporization , carbonization

Low power laser can affect on living tissue where photons must be absorbed by electronic absorption bands . Optical properties of tissue determine the interaction of laser at certain wavelength, power and exposure time [12].

The lasers in general have a lot of properties like monochromatic , spatial and temporal coherence, directionality and brightness, monochromatic laser has only minor importance for most of the medical applications [13].

From above properties, the brightness of laser has the greatest influence , the beam of laser with or without focusing, produces localized specific photochemical reaction and internal local heating . In addition they can be worked in CW mode or pulsed mode and can generate ultra-short pulses with femto second pulses [14].

(1-2) Literature survey :

Series	Researcher & year	Subject
1	Iijima et.al., (2000)	They studied the effect of exposure erythrocytes to the He-Ne laser (continuous wave, 632.8nm wavelength), with a power of (8.5) mw and irradiation led to red blood cells deformation [15]
2	Siposan and Adalbert, (2003)	They studied the effect of a low-power He-Ne laser on blood parameters. The authors noted that irradiation resulted in decreased viscosity, BSR, and changes in some erythrocytes [16].
3	Theodoro LH , et.al., (2006)	Studied the effect of Er:YAG and Diode lasers on the adhesion of blood components and on the morphology of irradiated root surfaces. The Er:YAG laser did not caused the adhesion of blood components, whereas the Diode laser inhibited the adhesion [17].
4	Jianhua Zhou, et.al., (2007)	This group explained the thermal damage in biological tissues caused by laser irradiation by using theoretical analysis .The tissue damage occurs sometime after the laser irradiation[18].
5	Ahmed A. Ibrahim , (2009)	Explained the effect of (He-Ne) laser radiation and viscosity of red blood cells on erythrocytes sedimentation rate (ESR) . The laser radiation reduce the (ESR) of blood samples [19].

6	MohammadAli Ansari and Ezeddin Mohajerani (2011)	They studied the mechanisms of laser-tissue interaction: optical properties of tissue and then explained the effects of these properties on laser penetration in tissue [20].
7	José Eduardo Cezar Sampaio , et.al. , (2012)	They showed the effect irradiation for Er,Cr:YSGG and Er:YAG laser on the adhesion of blood components on the root surface .They found (Er:YAG) laser was more effective in enhancing the adhesion of blood elements on root surfaces [21] .
8	Jaona H. R. et.al., (2014)	Studied the effects of short pulsed laser radiation on transit heating of human tissues . They examined an increasing of local radiation absorption in the tissue with short pulsed radiation and gold nanoparticles (GNPs) embedded in human tissue [22].
9	Shikha rathore and Basharath Ali (2014)	They explained the effect of laser radiation (He-Ne) on electrical conductivity of blood and then found the conductivity of the blood was changed [23].
10	K. Shurrab , (2014)	Theoretical study by simulation of temperature distribution due to COMSOL multiphysics in living biological tissues under laser irradiation and study of bio-heat equation , The best value obtained for mitigating thermal damage is (77C˚) (350K) at the laser treated area, the temperature is (62 C˚) (335K), which is the temperature of the tissue adjacent, at 0.5 s (time), 0.5 w (power) [24].

11	Flavia de paoli et.al., (2015)	They studied the damage of DNA for blood cells caused by low –level laser . They showed the damage in DNA of blood caused by exposure to low-level red and infrared lasers depending on fluence, power and emission mode [25] .
12	Muhammed Zeeshan (2016)	Stated the mechanism of laser / light interaction at cellular and tissue and study of influential factor for applications of low level laser therapy . The interaction between tissue with different source of light (conventional light or LED) but the use of laser is to be more favorable in interaction with tissue and cells [26].
13	M. Aliannezhadi, M. Minbashi,V.V.Tuchin (2018)	They showed the effect of laser intensity and exposure time on photo thermal therapy with nanoparticles heated by a 793-nm diode laser . The thermal distribution and thermal damage are estimated by solving the bio-heat transfer equation and the thermal damage function simultaneously by COMSOL multiphysic[27] .
14	Clarie Bost , (2019)	Studied heat transfer in biological tissue with thermal damage analysis . The result of numerical simulation of thermal damage due to electromagnetic heating of biological tissue taken by COMSOL multiphasic [28].
15	Zahra Al-Timimi, (2019)	Showed the Impact of laser (Nd:YVO4 Crystals,532nm) radiation on white blood cells

		.When the laser dose time is increased there is no further change which is observed in WBCs , while at laser dose for shorter duration, there is a marked increase in the optical absorbance of the Hgb, which minimizes laser-induced heating[29].
16	Marek Jasiński , (2020)	Modeling of Injury Process of Biological Tissue Containing Blood Vessel Caused by Laser Impulse by COMSOL multiphysics .The higher values of the temperature as well as the larger area of destructed tissue were obtained for computations with higher values of scattering coefficient [30].
17	Luca Brunese , Marcello , Claudio Tucci , Assunta Andrezzi , (2021)	Studied numerical analysis by COMSOL multiphysics for pulsating heat source effects in a tumor tissue , the most powerful result achieved using a pulsating heat source instead of a constant one is the decreasing of maximum temperature in any considered case, even reaching about 30% lower maximum temperatures [31].
18	MohamedA. Elblbesy (2021)	The refractive index of human blood measured at the visible spectral region by single-fiber reflectance spectroscopy , for control, the refractive index measured by the indicated method was significantly higher than anemic blood over the wavelengths in the visible spectral region [32] .

(1-3) Aim of work:

Study the effect of laser irradiation at different wavelength on the optical properties of human blood samples (normal and abnormal) , and adopting this method as a new physical method analysis to know the health and nature of the tested blood samples , and study the effects of bio-heat equation on normal blood in the visible range by using program of COMSOL multiphasic software .

(2-1) Properties of Laser:

A laser is a process of optical amplification of the energy produced by the electron when being transferred to a lower energy state from an excited state. The light produced by laser has many differences about conventional light. It is monochromatic that consist of photons with single wavelength. The light of laser is coherent in nature that means the light of laser has the same phase. The property of interference is used in diagnostic medicine. Lastly, the light of laser has low divergence that means high collimated beam [33].

Laser systems can be classified as continuous wave (CW) lasers and pulsed lasers. Whereas most gas lasers and to some extent also solid-state lasers belong to the first group, the family of pulsed lasers mainly includes solid-state lasers, excimer lasers, and certain dye lasers [34] .

The emitted light by the laser is coherent, meaning that all the photons are in the same phase, which makes the light of the laser beam of high intensity , that means electromagnetic ray has a wave property that can be named as (Coherent) that there is a constant relationship in the phase difference between the interfering waves, causing the constructive interference phenomenon [35].

Use of lasers in medicine has increased over the years , today lasers have begun to play an important role in medical systems and surgery[36]. They are used in various fields of medicine like diagnosis and treatment of cancer , dermatology , ophthalmology (Lasik and laser photocoagulation), optical coherence tomography . Lasers also find use in cosmetic applications like laser hair removal and tattoo removal [33] .

(2-2) Effect of Laser beam on Biological Tissue :

The monochromaticity property of laser light, attached to its singularity of wavelength, is a determinant factor for the interaction with biological tissue, since it needs to be absorbed in order to interact with any tissue or matter. Biological tissues have light receptors (chromophores) that are highly selective to the wavelength it absorbs. In the case of biological tissues, some common chromophores include hemoglobin, oxyhemoglobin, melanin and water. The polarized characteristics of laser light also influences this interaction, as different polarizations of light can be absorbed to different degrees by different biological tissue or matter. Broad-band lamps and Non-coherent light sources, such as light-emitting diodes (LEDs), have been successfully used in biophotomodulation therapy [37].

A laser can deposit a great amount of energy within a very small area (spot size), due to its collimation property, that allows the emission of non-divergent, parallel rays to generate minimum beam spread as they propagate over a distance [38]. The diameter of the beam influences the amount of energy delivered by the laser, as light energy gets concentrated with the reduction of the beam diameter. Ordinary light is non-collimated. As it travels, its diameter spreads out, the beam spot size increases in diameter, and the light loses energy on its way[37]. With non-collimated light beams, it is difficult to quantify the energy dosage delivered to its target from a distance, unless the beam is in direct contact with the tissue [39].

(2-3) Laser – Tissue interaction mechanisms :

There are many different mechanisms through which laser light can interact with tissues. For the most common interaction mechanisms for therapeutic and surgical applications will be divided into five broad classes:

1. **Photochemical interactions**: Photons excite molecules or atoms, making the molecules more likely to undergo chemical reactions with other molecules. In photodynamic therapy, for instance, a photosensitizer (a molecule that becomes reactive when it absorbs light and can therefore induce chemical reactions within other molecules or tissue) causes reactive oxygen species to form which lead to (cell death). Photodynamic therapy is increasingly widely used in oncology to destroy cancerous tumors [40].

2. Photo thermal interactions: photons are absorbed by a chromphore (a light-absorbing molecule) and converted into heat energy, which can cause a range of thermal effects from tissue coagulation to vaporization. Applications include tissue cutting and welding in laser surgery [41].

3. Photo ablation: High-energy, ultraviolet (UV) photons are absorbed and, because they are more energetic than the chemical bonds holding the molecules together, cause the dissociation of the molecules. This is followed by rapid expansion of the irradiated volume and ejection of the tissue from the surface. This is used in eye (corneal) surgery, among other applications [42] .

4. Plasma-induced photo ablation: A free electron is accelerated by the intense electric field in the vicinity of the laser beam. By colliding with a molecule and freeing another electron, it initiates a chain reaction of similar collisions, resulting in a plasma: a soup of ions and free electrons. One application of this is in lens capsulotomy to treat cataracts [43].

5. Photo disruption : It is the mechanical effects that can accompany plasma generation, such as bubble formation, cavitation, jetting and shockwaves. All these mechanisms illustrate in figure (2-1) below [34] :

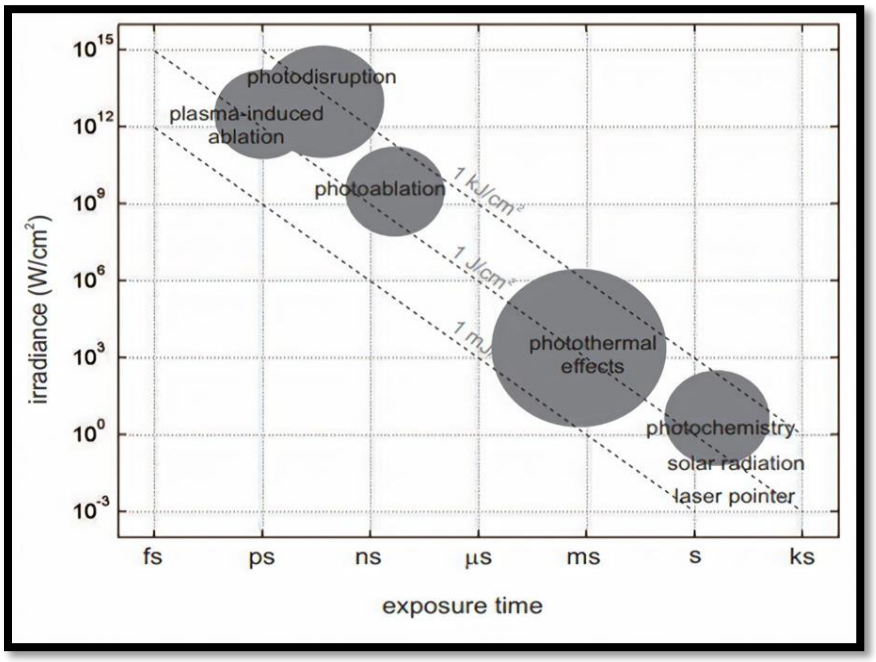


Figure (2-1) : Different types of laser-tissue interaction[34]

(2-4) Bioheat transfer in living tissue:

Bioheat transfer is the study of the transport of thermal energy in living systems. Because biochemical processes are temperature dependent, heat transfer plays a major role in living systems. Also, because the mass transport of blood through tissue causes a consequent thermal energy transfer, bioheat transfer methods are applicable for diagnostic and therapeutic applications involving either mass or heat transfer[44].

The effects of blood flow on heat transfer in living tissue have been examined for more than a century, dating back to the experimental studies of Bernard in 1876. Since then, mathematical modeling of the complex thermal interaction between the vasculature and tissue has been a topic of interest for numerous physiologists,

physicians, and engineers [45]. A major problem for theoretical prediction of temperature distribution in tissue is the assessment of the effect of blood circulation, which is the dominant mode of heat removal and an important cause of tissue temperature inhomogeneity [46].

2-4-1 Photo thermal Effects

Thermal effects are perhaps the most widely encountered form of tissue-laser interaction in clinical practice. In photochemical effects, such as photodynamic therapy, there is often a specific reaction pathway that leads to tissue damage. Here, there is no specific pathway, and the photons may be absorbed by any biomolecule and still lead to a thermal effect. Heat energy is deposited in the tissue by the absorption of light and its subsequent conversion to heat via vibrational relaxation. This causes a rise in temperature of the tissue. Also the heat will diffuse through the tissue causing a rise in temperature in the surrounding tissue. The damage done to the tissue depends on the temperature that is reached, and the duration at which it is held at that temperature. There are many different and varied medical applications that use a thermal interaction, from vaporization of tumors, to welding gastrointestinal ulcers, and the removal of skin marks such as port wine stain birthmarks or tattoos [47].

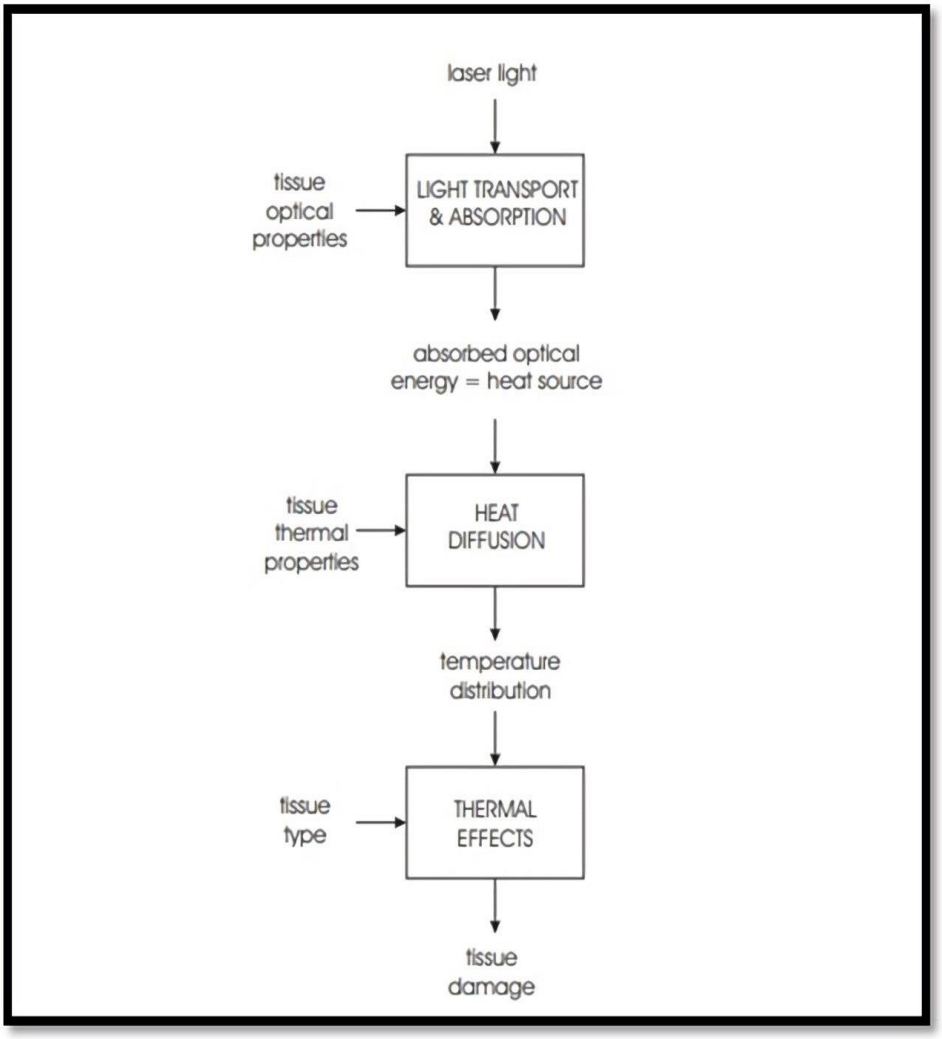


Figure (2-2):The various aspects involved in thermal interactions of light with tissue [47].

According to figure (2-2) which shows how light interacts thermally with tissue and take into account the fact that soft tissue conducts heat. Finally , the last part of figure (2-2) , which is shows what happens to the tissue once it has reached a certain temperature, the tissue is consists of collagen, water, hemoglobin and perhaps a few other chromophores, such as melanin.

• Cells: this is the part of this tissue that biologists have conventionally concentrated on. For our purposes they are often treated as water-filled, although the proteins in

certain cells can be crucial to some applications (such as the hemoglobin in red blood cells is to port wine stain treatment).

• Extracellular matrix (ECM): this is a fibrous scaffold among which the cells nestle, and which gives tissue most of its stiffness and structure. It is made from collagen and elastin and other glycoproteins and proteoglycans. The ratio of the amount of ECM to number of cells varies widely depending on the type of tissue. Liver and muscle, for instance, are low in ECM, whereas bone, tendon and the retina are largely ECM. Figure (2-3) shows images of extracellular matrix , the collagen in ECM is of interest when considering thermal effects because it breaks down at temperatures well below 100◦C [48].

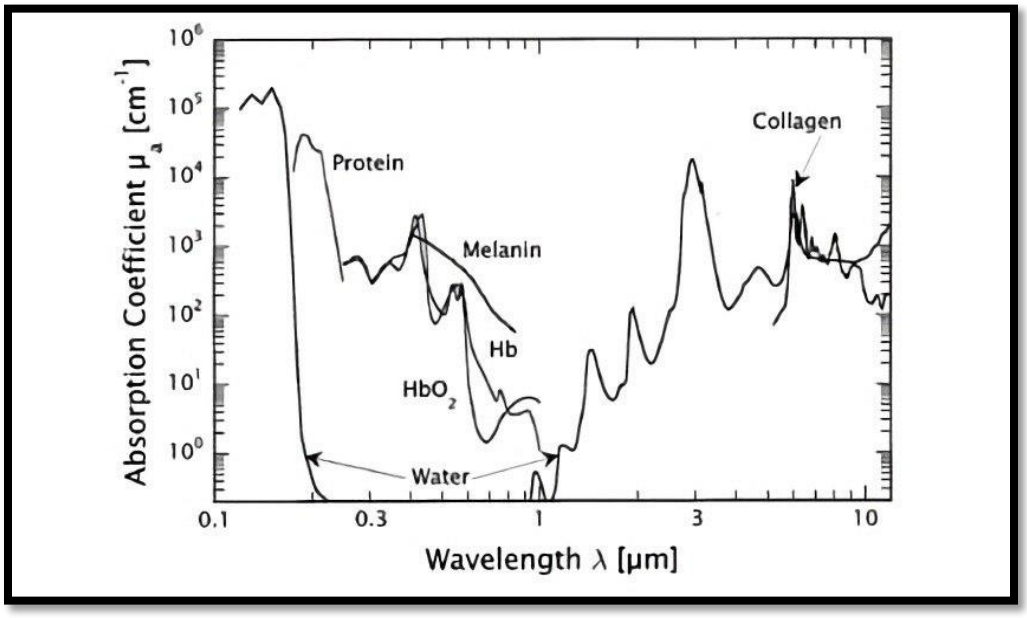


Figure (2-3) :Absorption coefficient spectra for various tissue constituents. Note the peak in the hemoglobin (Hb and HbO_2) absorption at 577 nm used in port wine stain treatment [48].

2-4-2 The Pennes Model

The first mathematical relationship that described the heat transfer between blood and tissue is presented by Pennes in 1948. The Pennes' model for describing the energy balance of tissue metabolism and blood perfusion in a living tissue is designed originally for predicting temperature fields in the human forearm. For simplicity of the modeling analysis, Pennes made three assumptions that the rate of heat production by tissue, the volume flow of blood per unit volume of tissue per second and the tissue specific thermal conductivity were both considered uniform throughout the forearm[49]. Although the Pennes bioheat model is developed based on the experimental analysis of the human foreman, it can be used to quantitatively calculate the rate of heat transfer in any perfused tissues. It has been adopted by many authors who have developed mathematical models of heat transfer in living tissues so that it becomes well known as the bioheat transfer equation. According to the human forearm temperature measurement results, Pennes quantitatively analyzed the brachial arterial blood and tissue temperatures and further evaluated the applicability of heat flow theory to the forearm in terms of local rate of tissue heat production and volume flow of blood [50]. The principal theoretical contribution of Pennes shows that the rate of heat transfer between blood and tissue is proportional to the product of the volumetric perfusion rate and the difference between the arterial blood temperature and the local tissue temperature. As Pennes was not certain of the extent of thermal equilibrium between capillary blood and surrounding tissue, he presumed the physical conditions of the capillary circulation almost complete equilibrium. According to his suggestion that the arterial blood temperature is considered uniform throughout the tissue, the thermal energy balance for perfused tissue is expressed in the following form[49] :

$$\rho_t c_t \frac{\partial T}{\partial t} = \nabla . (k_t \nabla T) - W_b c_b (T - T_a) + q_m \qquad (2\text{-}1)$$

where ρ is the density, c is the specific heat, k is the thermal conductivity with the subscripts t and b referring to tissue and blood domain, respectively, T is the temperature, q_m heat generations due to metabolism; W_b is the blood perfusion rate; and T_a is the arterial blood temperature. Note that q_m is 0.000 lcal/(cm^3.s) and W_b ranges from 0.0002 to 0.0005 g/(cm^3.s). The four terms in Equation (2-5) are intended to represent thermal energy storage, thermal energy diffusion, convective energy (i.e., energy perfusion of solids by liquids, primarily by blood), and metabolic heat generation [50].

(2-5)The Blood :

The blood is a tissue constitute from a suspension of cells in liquid called plasma. Blood accounts for 7% of the human body weight, with an average density of approximately 1060 kg/m^3 , very close to pure water's density of 1000 kg/m^3 . Blood is contain of red blood cells, white blood cells, plasma and platelets, a connective tissue, which is very essential for many organisms such as human and animal[51], and so important to jobs, a transfer of materials (food and oxygen), vitamins and waste (carbon dioxide) and hormones to all tissues and cells of the body and the degree of natural temperature is 37 degrees Celsius, figure (2-4): shows the components of blood [52].

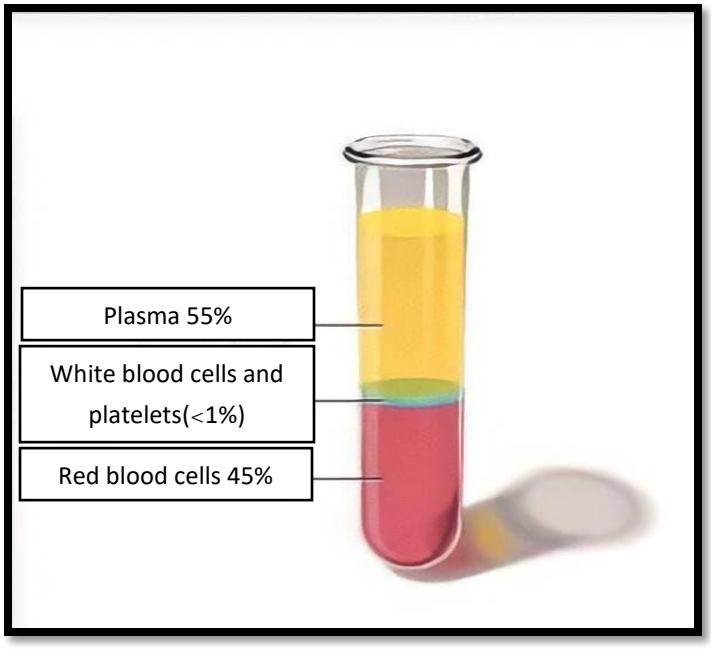


Figure (2-4): The components of blood [52]

2-5-1 Plasma:

Plasma is liquid material in blood, which by itself is straw-yellow in color About 55% of blood is, a fluid . The blood plasma volume totals of 2.7– 3.0 liters in an average human. It is essentially an aqueous solution containing 92% water, 8% blood plasma proteins, and trace amounts of other materials[53]. Plasma circulates dissolved nutrients, such as glucose, amino acids and fatty acids (dissolved in the blood or bound to plasma proteins), and removes waste products, such as carbon dioxide, urea, and lactic acid. Other important components include:

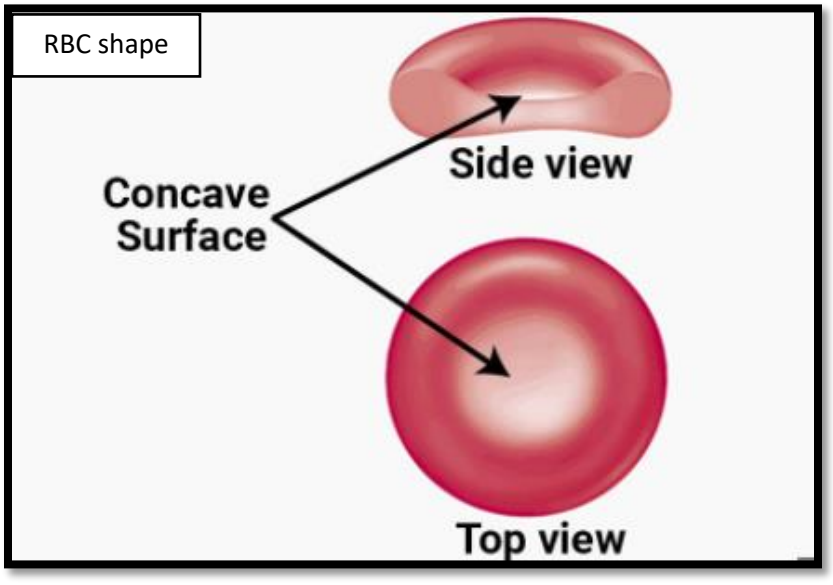
- Serum albumin
- Blood-clotting factors (to facilitate coagulation)
- Immunoglobulins (antibodies)
- lipoprotein particles

- Various other proteins
- Various electrolytes (mainly sodium and chloride)

The term serum refers to plasma from which the clotting proteins have been removed [54].

2-5-2 Red Blood Cell (Erythrocytes) :

Cells are disc shaped concave – sided, and concave surface in order to increase the gas exchange area, its function transport of gases and features, (red blood cells, RBC) can change shape under a given level of applied stress, a flexible membrane cell position to pass even in the narrowest capillaries[55]. Arise from the red marrow in large bones and renewed every 120 days and breaks up in the liver , spleen and go to the bile to participate in contents it has red color to the presence of material hemoglobin consists hemoglobin protein and iron, figure (2-5): show Red Blood cell [52].



Figure(2-5): Shape of Red Blood cell [52]

Shape change of erythrocytes under applied forces (i.e., shear forces in blood flow) is reversible and the biconcave-discoid shape, which is normal for most mammals, maintained after the removal of the deforming forces. In other words, erythrocytes behave like elastic bodies, while they also resist shaping change under deforming forces. This viscoelastic behavior of erythrocytes is determined by the following three properties. Approximation the number of RBC in men's 4 - 5 million in the women's 4 - 4.5 million[56].

2-5-3 White Blood Cells (Leucocytes):

White blood cells (Leucocytes) are large opaque blood cells-which mean that they appear to be solid rather than transparent. Leukocytes form a protective, movable army that helps defend the body against damage by bacteria, viruses, parasites, and tumor cells [57].

White blood cells differ from red blood cells by the absence of hemoglobin, but they are distinguished from them by the presence of these cells have a nucleus, and in fact the color is praying however, transparent but appear white under a light microscope as a result of the reflection of light on it [58].

Five types can be distinguished of white blood cells when examining the blood sample under the microscope and this distinction depends its divisions and on the type of dye color acquired by the cell when some dyes are used for the fabric shaped like a nucleus and types of white blood cells, figure (2-6) represents schematic for the different types of white blood cells [59] .

The differential count can be given for the different types of white blood cells, as follows: Neutrophils (about 5% to 6% of white blood cells and lymphocytes) about 25% to 40% of white blood cells form mononuclear cells (about 3% to 7% of white

blood cells and form eosinophil (about 1% to 3% of blood cells white blood cells, and basophiles (about 1%) of white blood cells [60].

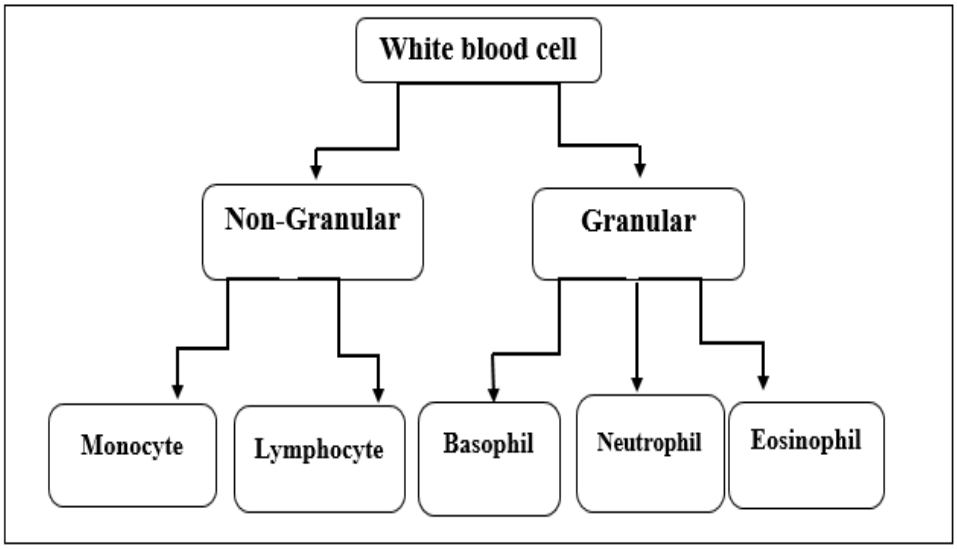


Figure (2-6): Schematic for the different types of white blood cells [60].

White blood cells are the cells that provide protection to the body from disease and their number is less than red blood cells as it's between seven hundred and fourteen erythrocytes find white balls and one as she varying sizes and shapes, with one core as it is larger than red blood cells; of between (5000-10000) cell in a cubic millimeter. And it is one of the most important means of defense of the antigens (antibody generators) in the body and their number is increasing at the disease [61].

2-5-4 Blood Platelets (Thrombocytes) :

Platelet-rich plasma (PRP) is a volume of plasma fraction of antilogous blood having platelet concentrations above baseline whole-blood values due to processing and concentration ,figure(2-7). PRP is used in various surgical fields to enhance soft-tissue physiological concentrations of autologous platelets at the site of tissue damage[62]. Blood platelets (thrombocytes) are very small disc –shaped don't have any nuclei.

They have an important role in blood clotting. Platelets are fragments of cells in blood and are another important part of the clotting process. They work with the clotting factors in plasma to prevent bleeding. Platelets can also be collected by apheresis can collect enough platelets so that they don't have to be combined with platelets from other donors [57]

Figure(2-7): Platelet [52]

(2-6) Physical properties of Human Blood :

2-6-1 Color:

Blood color varies with its oxygen content. High oxygen content bright red. Low oxygen content dark red [63].

2-6-2 Blood Viscosity :

Biochemical data, such as levels of fibrinogen, cholesterol, or albumin, globulin ratios, serve not only characteristic values in health and disease, but correlated with the blood viscosity factors (such as blood viscosity, plasma viscosity, aggregation of red cells) from pattern of blood viscosity functions[64] .

2-6-3 Osmotic Pressure :

One important chemical reaction of blood plasma is that it contains sufficient quantities of dissolved proteins. Salts and other biomolecules to maintain appropriate osmotic pressure in the body. This means that the plasma must neither draw water out of the cells, nor must it force water into the cells. It must neither be hypertonic- containing more salts and dissolved molecules- nor hypertonic-containing fewer salts and dissolved molecules to water [65].

2-6-4 Density of Blood :

Density is defined as a mass per unit volume. Blood plasma and its contents are known as whole blood. It is proportional to hematocrit or, the total protein concentration of blood; only to a minor extent is blood density influenced by other plasma solutes. The density dilution method can be used for the determination of distribution volumes, of flow through organs [66]. It depends on the presence of soluble substances in the plasma such as red blood cells and protein, and its value for men ranges between (1.067-1.075) g/cm^3. For women, it ranges from (1.0561-1.051) g/cm^3 [67].

2-6-5 Temperature:

They are fixed in the body with some differences in it from one organ to another according to the need of this organ for heat in order to perform its main function. For example, the temperature of the liver is equal to 40-41, while the brain's temperature is less than (37 ° C), and the general average body temperature ranges between 36.8-37.8 ° C [58].

(2-7) Blood Functions:

2-7-1 Respiratory:

The blood transports oxygen from the respiratory organs (lungs) to the tissues by means of hemoglobin for red blood cells and transports carbon dioxide from the tissues to the lungs to be excreted from the body [68].

2-7-2 Nutritive:

The blood transports and distributes nutrients from the digestive system to all tissues of the body[68] .

2-7-3 Regulation of body temperature :

Blood helps regulate body temperature, as it distributes heat to different parts of the body [69].

2-7-4 Regulating metabolism :

The blood carries the various enzymes from the places of their manufacture to the organs different body in order to perpetuate the processes of construction and demolition in the cells of the body, and these processes are called (Metabolism) [70].

2-7-5 Defense:

The body is protected by white blood cells for their ability to devour the microbes entering the body and thus protecting the body from disease, as there are antibodies in blood cells that protects the body from bacterial infection [71].

2-7-6 Transport and regulation of hormone:

The blood regulates the secretion of hormones from its glands and maintains a balanced ratio in the blood, and the blood transports these hormones to their places of work [72].

2-7-7 Water balance :

The blood works to maintain the amount of water in the body, by removing excess water about the needs of the body through the kidneys and skin [70].

2-7-8 Coagulation blood :

The bleeding resulting from a blood vessel injury is stopped by blood clotting by the protein Fibrinogen found in the blood plasma. This protein is generated in the liver, which plays a key role in blood clotting [72].

(2-8) Anemia:

Anemia is a condition characterized by a decrease in the concentration of hemoglobin in the blood as shown in figure (2-8). Hemoglobin is necessary for transporting oxygen to tissues and organs in the body. The reduction in oxygen available to organs and tissues when hemoglobin levels are low is responsible for many of the symptoms experienced by anemic people. The consequences of anemia include general body weakness, frequent tiredness, and lowered resistance to disease. Anemia can be a particularly serious problem for pregnant women, leading to premature delivery and low birth weight. It is of concern in children since anemia is associated with impaired mental and physical development. Overall, morbidity and mortality risks increase for individuals suffering from anemia[73]

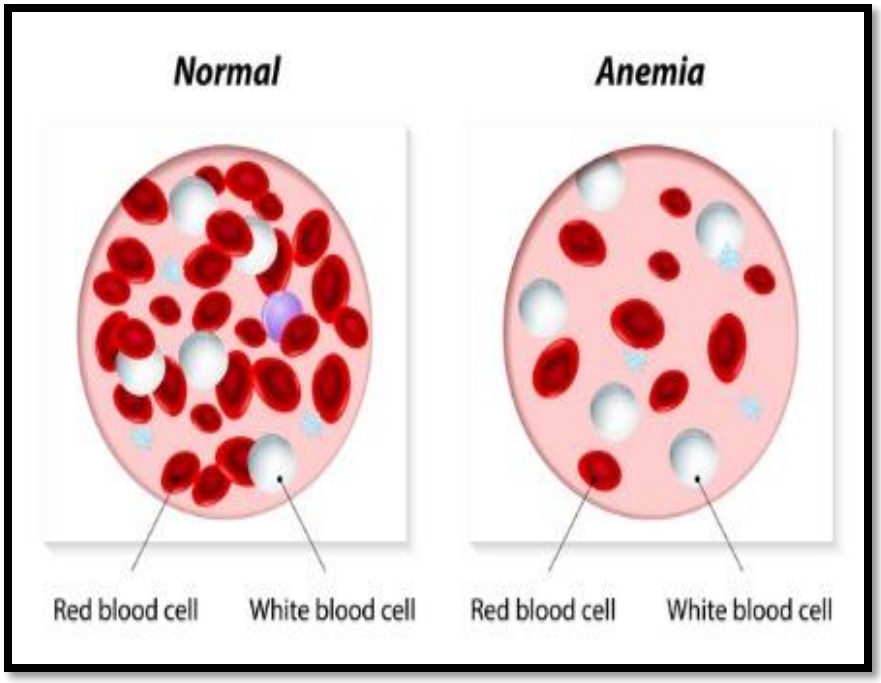


Figure (2-8): normal blood and anemia [73]

In order to make a generalized approach to the diagnosis of anemia, established a reference range for normal blood hemoglobin concentration, depending on age and sex . According to this criterion, anemia is present if the blood concentration of hemoglobin falls below(13 g/dl)in men or (12 g/dl) in women [74].

Anemia is classified as mild, moderate, or severe based on the concentrations of hemoglobin in the blood. Mild anemia corresponds to a level of hemoglobin concentration of 10.0-10.9 g/dl for pregnant women and children under age 5 and 10.0-11.9 g/dl for non pregnant women. For all of the tested groups, moderate anemia corresponds to a level of 7.0-9.9 g/dl, while severe anemia corresponds to a level less than 7.0 g/dl [73].

2-8-1 Causes of anemia :

The volume of red blood cells decreases when hemoglobin decreases, and at a later stage it affects the number of red blood cells, which also decreases, so it becomes few in number, and there are many causes for hemoglobin decreases:

the most important of which is the lack of iron, vitamin B12 and folic acid in the body [75].

2-8-2 Types of Anemia:

There are several types and classifications of anemia. The occurrence of anemia is due to the various red cell defects such as production defect (aplastic anemia), maturation defect (megaloblastic anemia), defects in hemoglobin synthesis (iron deficiency anemia), genetic defects of hemoglobin maturation (thalassemia) or due to the synthesis of abnormal hemoglobin (haemoglobinopathies, sickle cell anemia and thalassemia) and physical loss of red cells (hemolytic anemia's). This is a condition in which the body lacks the amount of red blood cells to keep up with the body's demand for oxygen. Understanding the different classifications can help to recognize the symptoms and also to avoid anemia in the first place[76].

2-8-3 Thalassemia :

Thalassemia is an inherited blood disorder which cause the body to make fewer healthy red blood cells and less hemoglobin . The body makes an abnormal form of hemoglobin. Hemoglobin is the protein molecule in red blood cells that carries oxygen. as shown in figure (2-9) [77].

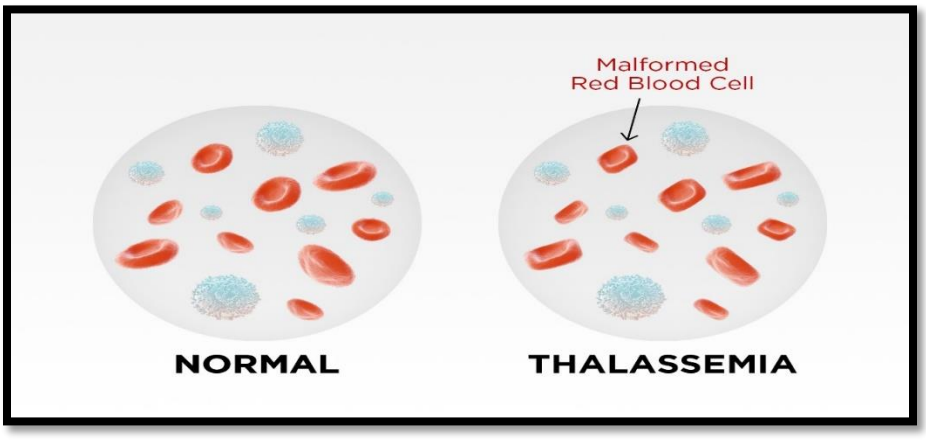


Figure (2-9): normal blood and thalassemia [77].

The two major types of thalassemia are alpha- and beta thalassemia. Thalassemia affect both males and females. Hemoglobin in red blood cells has two kinds of protein chains: alpha globin and beta globin. If the body doesn't make enough of these protein chains, red blood cells don't form properly and can't carry enough oxygen. Genes control how the body makes hemoglobin protein chains, when these genes are missing or altered, thalassemia occur. thalassemia are passed on from parents to their children through genes [77].

Symptoms of thalassemia are caused by a lack of oxygen in the blood stream. People who have alpha or beta thalassemia can have mild anemia, People with beta thalassemia intermediate have mild to moderate anemia [78,79]. They may also have other health problems including slowed growth and delayed puberty, bone problems and an enlarged spleen. People with beta thalassemia major have severe thalassemia and other serious health problems Pale and listless appearance, Poor appetite, Dark urine, Slowed growth and delayed puberty, Jaundice, Enlarged spleen, liver and heart, Bone problems [80] .

(2-9) Optical properties of blood :

2-9-1 Optical properties :

A. Transmittance:

Means that it is the non-absorbed part of the incident energy after it passes through the living tissue, and this means an increase in the depth of penetration of the laser light into the tissue, and that the depth of penetration is the function of the wavelength, an example of this is the absorption of water in the cell where it is little within the visible region in the electromagnetic spectrum (transmission increase), while an increase in water absorption increases with higher wavelengths (decreased transmittance) [81].

$$T = \frac{I}{I_0} = e^{-\alpha t} \qquad (2\text{-}2)$$

Where :

t : thickness of material (cm)

α : absorption coefficient (cm^{-1})

The ratio (I / I_0) is known as transmittance (T), which is the ratio between the intensity of the transmitting light ray to the intensity of the incident ray and is given by the following relationship [82].

B. Absorbance :

Absorption is the process of transferring energy from light to the target substance which results in energy loss and is defined by the absorption coefficient [83]. The main human tissue absorbers of laser light are melanin, hemoglobin and water . According to Beer-Lambert law we can determine the amount of absorption from [84] , and all of phenomena shown in figure (2-10) [12] :

$$A = \alpha \ell c \qquad (2\text{-}3)$$

Where :

$$A = \log_{10}(\frac{I_1}{I_\circ}) = \alpha \ell c \qquad (2\text{-}4)$$

$$\alpha = \frac{4\pi\kappa}{\lambda} \qquad (2\text{-}5)$$

Where :

A: absorbance

I_o: incident intensity

I_1: transmitted intensity

λ: wavelength

α: molar absorptivity

κ : extinction coefficient

c: concentration of materiel

ℓ : distance of light passed through material

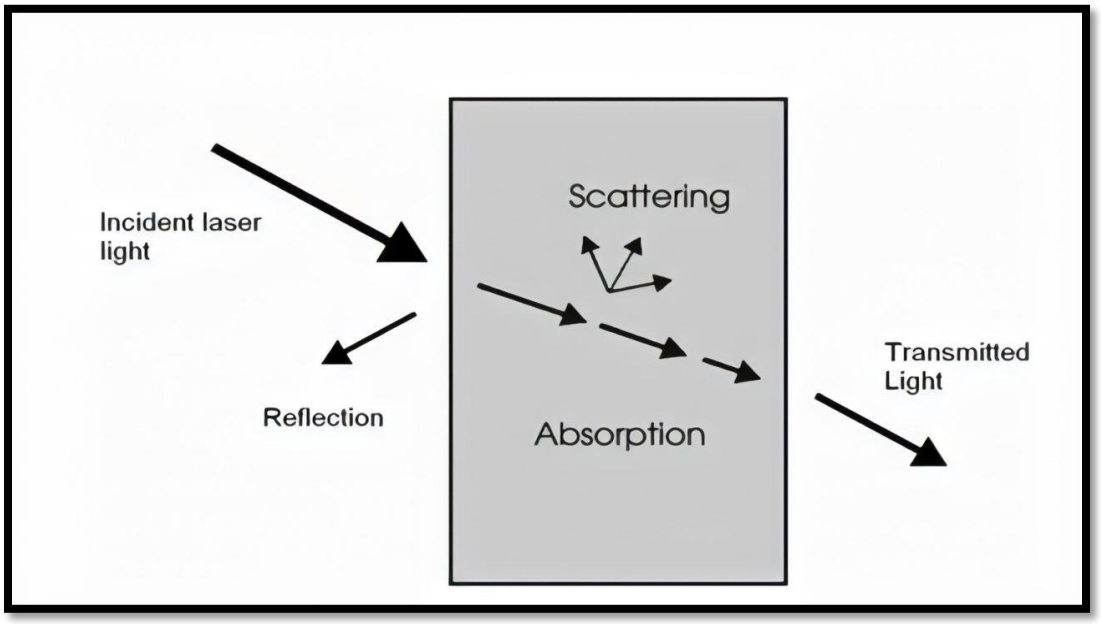


Figure (2-10) : Propagation of light in tissue[40]

2-9-2 Optical properties :

A. Absorption Coefficient :

The absorption coefficient can be calculated by the relationship [85] :

$$\alpha t = 2.303 \log I/I_0 \qquad (2-6)$$

Since the value of ($\log I/I_0$) represents the absorbance (A), the material's absorption of the incident rays causes an electronic activity that may lead to the disintegration of its molecules if the value of the absorbed energy is greater than the value of the disintegration of one of the bonds or its transfer to a higher energy level[86,87], as the possibility of absorption increases Increasing the concentration

of matter in the lower energy level and increasing the number of photons of the incident rays.

And we get the formula for the absorption coefficient as follows[85]:

$$\alpha = 2.303\left(\frac{A}{t}\right) \qquad (2-7)$$

B. Extinction Coefficient :

The amount of energy absorbed by the material from the energy of the incident photon [88]. The extinction coefficient is calculated using the following equation [89]:

$$k = \frac{\alpha\lambda}{4\pi} \qquad (2\text{-}8)$$

C. Optical Conductivity:

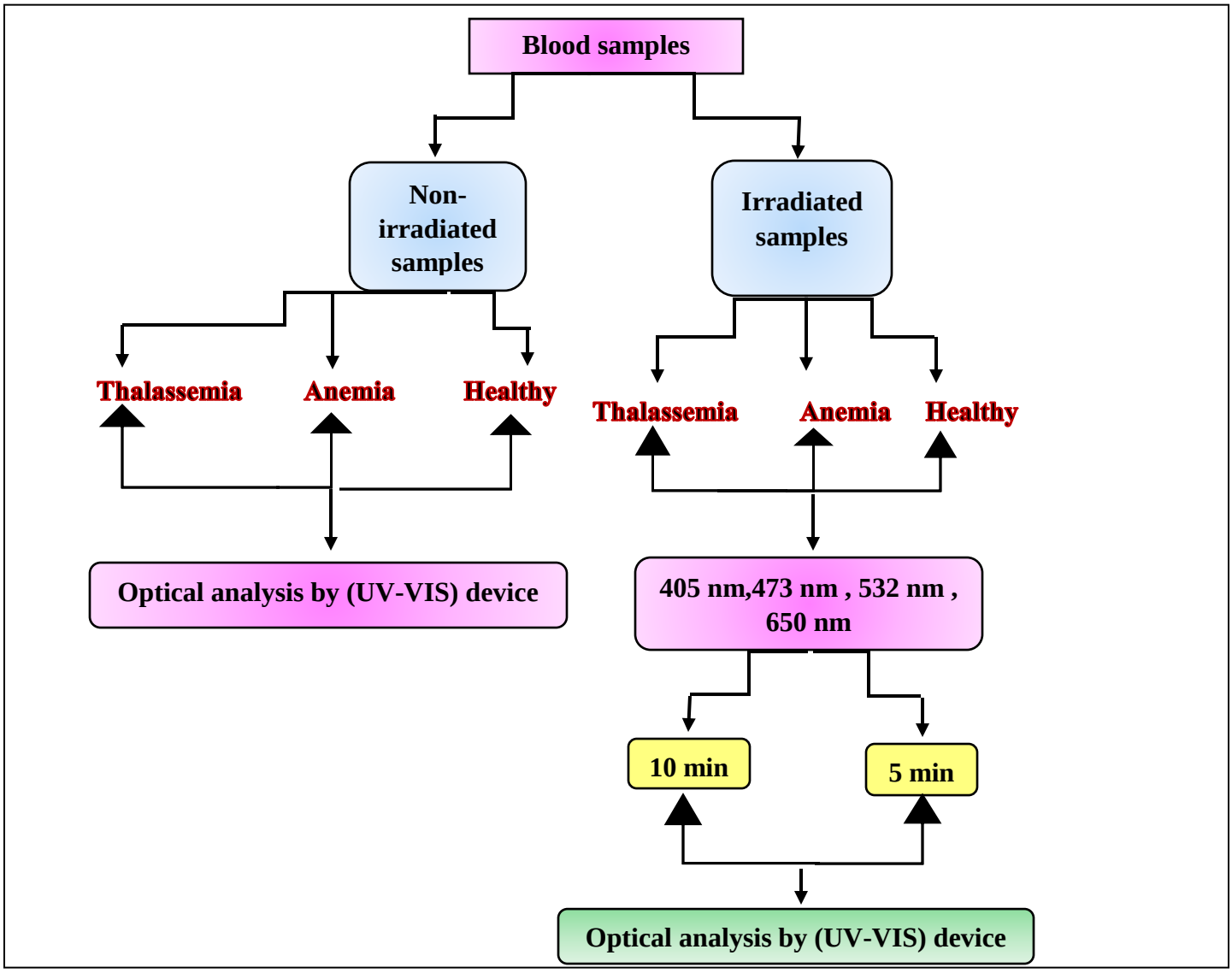
Optical conductivity is generally defined as electrical conductivity in the presence of an alternating electric field, the term (photovoltaic) here covers all frequencies and is not limited to the visible range of the spectrum. The optical conductivity is related to the speed of light through the following equation [90]:

$$\sigma_{\text{opt.}} = \frac{\alpha\, nc}{4\pi} \qquad (2\text{-}9)$$

Part One : Experimental Part

(3-1) Introduction :

This chapter includes an explanation of the materials used in experiments to study the effect of laser beams at wavelengths (405 nm , 473 nm , 532 nm , 650 nm) on healthy blood samples, anemic blood samples and thalassemia samples of human, this chapter includes also the method of preparing these samples and an explanation of the measurement methods and devices used in optical measurements ,as shown in figure (3-1) .



Figure(3-1) : Work Scheme

(3-2) The material used in the experiment :

3-2-1 Blood samples collection tubes (EDTA tube) :

A number of cylindrical glass tubes were used containing an anticoagulant substance called Ethylene Diamine Tetra Acetic Acid (EDTA). To preserve the components of blood cells from damage after taking blood samples from people through the syringe, and after placing the blood in the anticoagulant tube, it is required to move the tube slowly until the anticoagulant substance (EDTA) is completely and homogeneously distributed over the blood components inside the tube with a purple stopper.

3-2-2 Blood samples collection tubes (Plain tube):

It is a plastic cylindrical tubes that do not contain anticoagulation elements, which are used to divide blood samples after adding them in EDTA tubes for the purpose of the irradiation process ,

3-2-3 Glass slides:

In the current study, thin transparent glass slices were used, each slice 1 mm thick. The glass slide is used by placing a drop of blood sample at its end, and then the blood is wiped over it.

3-2-4 Centrifuge:

This device is used in medical laboratories to separate the components of blood from each other. The working principle is the centrifugal force that makes the particles that are more dense in weight at the bottom of the tube and then the lower ones higher. It contains an electric motor that rotates at a high speed and its speeds can be controlled according to need.

The rotation helps to mix or isolate materials by centrifugation and this is done by the motor that rotates at a speed of 2000 to 3000 revolutions per minute and the rotation depends on the time specified by the operator by hand, figure (3-2).

Figure (3-2) : Centrifuge device

3-2-5 Plastic pipette :

The plastic pipette was used, which is a manual pipette with gradations, one end of the plastic pipette is swollen and the other end is open , the plastic pipette is used to withdraw liquids and transfer them to the place to be placed, as the pipette tip is immersed With the fluid to be withdrawn, then press on its swollen tip to draw blood and place it in the designated place .

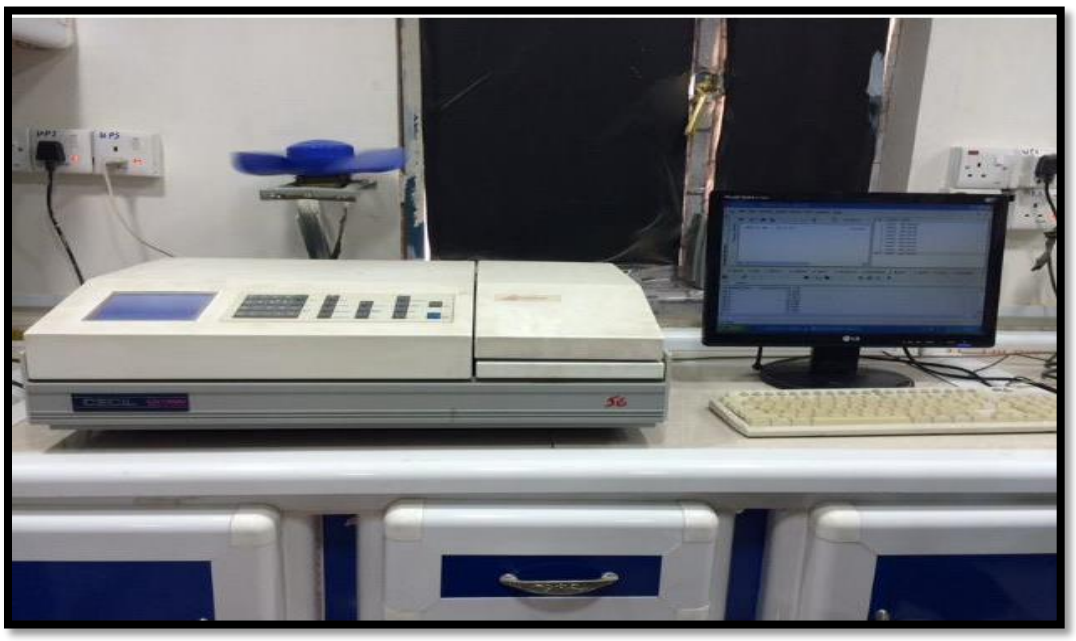
3-2-6 Glass cuvette :

Two glass cells were used in the current study , where the thickness of the cell is (1 cm) , the two cells were used in a double-beam spectrophotometer for the purpose of measuring and recording the absorbance spectra of the blood sample.

3-2-7 Optical measurement (Double- Beam Spectrophotometer) :

An English-made double beam spectrophotometer (CECIL CE-7500) working in the ultraviolet and visible regions with a range of wavelengths (190-1100nm) within the electromagnetic spectrum was used to measure the absorbance of the prepared blood samples and record its spectra as In the figure (3-3) which shows a photograph of the device used in the measurement, a double-beam spectrophotometer is used to

record the absorption spectra of the samples in terms of the wavelength of the light beam, this device is characterized by containing two beams of light where the source ray beam is divided by the beam splitter into two beams of equal intensity as it passes the first passes through the reference sample and is called the reference beam and then goes to photo detector No. (1) and the second passes through the sample whose absorbance is to be measured to photo detector No. 2. The two missing parts of the light rays through reflection or absorption by the material is equal for both paths, and the difference between the intensity of the two light beams represents the absorbance of the blood to be found only, where the examination sample was placed at the hole of the sample beam in the spectrometer, while the reference sample was placed at the aperture of the reference beam, and thus the absorbance of the sample was measured after subtracting Reference absorbance by the device self .



Figure(3-3) : Double- Beam Spectrophotometer

3-2-8 Lasers :

In the practical experiments of the current study, two types of lasers were used (solid-state lasers , semiconductor lasers) and of four wavelengths (532nm,405,473,and 650 nm) with a continuous wave, where the output beam of the transverse single mode (TEM_{00}) lasers with Gaussian beam distribution . The beam waist lasers beam for deferent wavelengths (405 nm , 473 nm , 532 nm , 650 nm) is (1 mm , 1 mm ,0.5 mm, 1.75 mm) respectively .

3-3 Preparation of the samples and the laser irradiation :

Blood samples were collected from 27 donors, women and children, whose ages ranged between (12-30) years, where (9) had healthy blood and did not suffer from diseases, (9) had anemia and (9) had thalassemia, (1.5 ml) of donor blood was drawn from the antecubital vein in front of the elbow joint. After that, the drawn blood was placed in laboratory glass tubes containing an anticoagulant substance (EDTA), then the tubes were moved quietly so that the blood was homogenized with the anticoagulant substance. The samples were divided into (8 groups) for each case, that is, in the case of (healthy, anemic, Thalassemia), where these groups were subjected to irradiation of four wavelengths (405, 473 nm, 532 nm, 650nm) and at different time periods (5 min, 10 min), while keeping three samples without irradiation from the blood of the donors (healthy, anemic, thalassemia) and these samples are called samples Control or non-irradiated samples.

Healthy blood samples, anemia and thalassemia were irradiated vertically at a distance of 10 cm from the surface of the blood sample. The figure (3-4) below shows the laser system that was used in the current study. On the other hand, the plasma was separated from the blood samples by a centrifuge, where it was at a speed of (2000 cycles) and a time of (5 minutes) for the purpose of sedimentation of

the high-density substance at the bottom and keeping the low-density substance at the top. After that, the absorbance of the plasma was measured for healthy blood .

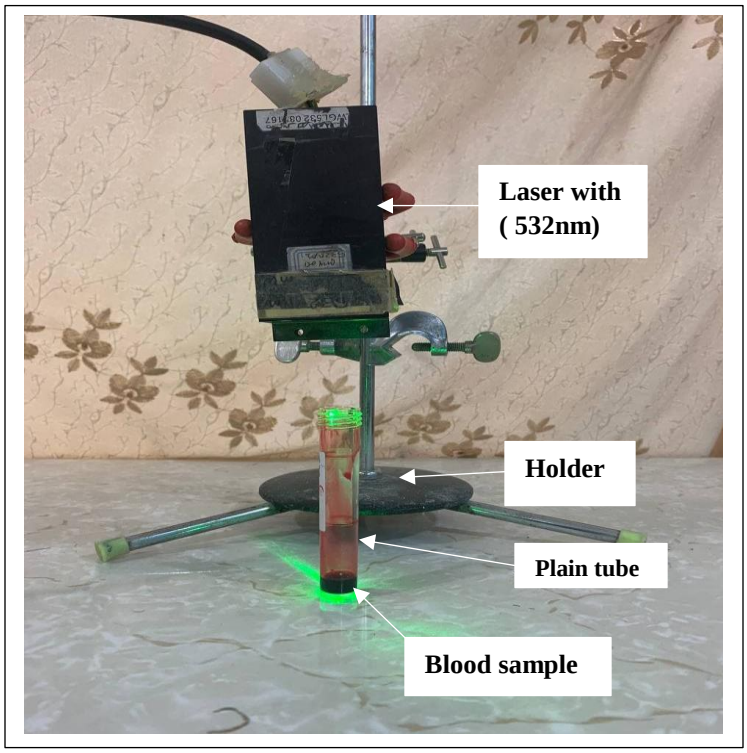


Figure (3-4) : experiment setup

3-4 Preparation of the blood slide :

Using the wedge method, blood slide was prepared on thin glass slides to obtain thin films. Where a drop of well-mixed blood was placed on the slide using a capillary tube so that it was close to one end (about 1 cm from the edge) as in Figure (3-5 A). Another slide with sharp edges was placed to spread the blood drop on the first slide, where it was placed in front of the blood and moved back to touch the blood drop as in Figure (3-5 B), which pushes the blood to spread along the width of the slide as in Figure (3-5 C). Taking into consideration that the distributed slide has a smooth end to prevent the end of the slide from making an irregular smear. After that, a smear was made by distributing the blood drop at an angle of about

(30^{o}-40^{o}), then the smear was left in the air for 5 minutes for the purpose of drying, as shown in Figure (3-5 D).

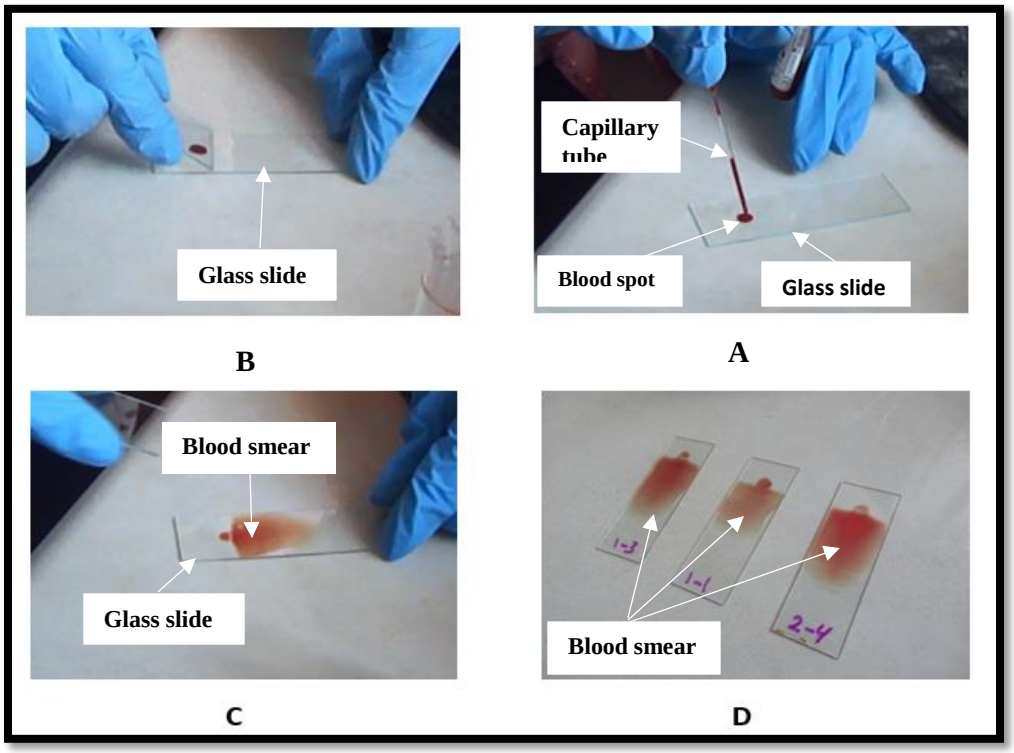


Figure (3-5) : Steps for preparing a blood slice

Part Two: Simulation Part

3-5 Simulation Program :

In this part , a simulation program is performed for a better understanding of the heat generated in blood sample and diffusion to surrounding under illuminating with laser light , this simulation was done by using (COMSOL multiphasic 5.3),computer simulation has become an essential part of science and engineering.

Digital analysis of components, in particular, is important when developing new products or optimizing designs. Today, a broad spectrum of options for simulation is available; researchers use everything from basic programming languages to various high-level packages implementing advanced methods.

A computer simulation environment is simply a translation of real world physical laws into their virtual form. How much simplification takes place in the translation process helps to determine the accuracy of the resulting model. It would be ideal, then, to have a simulation environment that includes the capability to add any physical effect to the any model. It's a flexible platform that allows users to model all relevant physical aspects of their designs.

3-6 Sample description:

A cylindrical symmetry of blood tube with radius (R) and thickness tube (d) of blood tube is proposed . The blood tube radius is (5 mm) , and this tube filled with homogenous solution (blood) is proposed .

The tube that filled with blood exposed to CW laser with wavelength (650 nm) and output power is (20 mW) at exposure time (5 , 10)min .

The response of (photo –thermal) for the blood grow from absorption of incident light power was tested by COMSOL multiphysics (model of time depending heat

transfer).metabolic heat generation ,the structure of the sample described in figure (3-6) as a geometrical mesh.

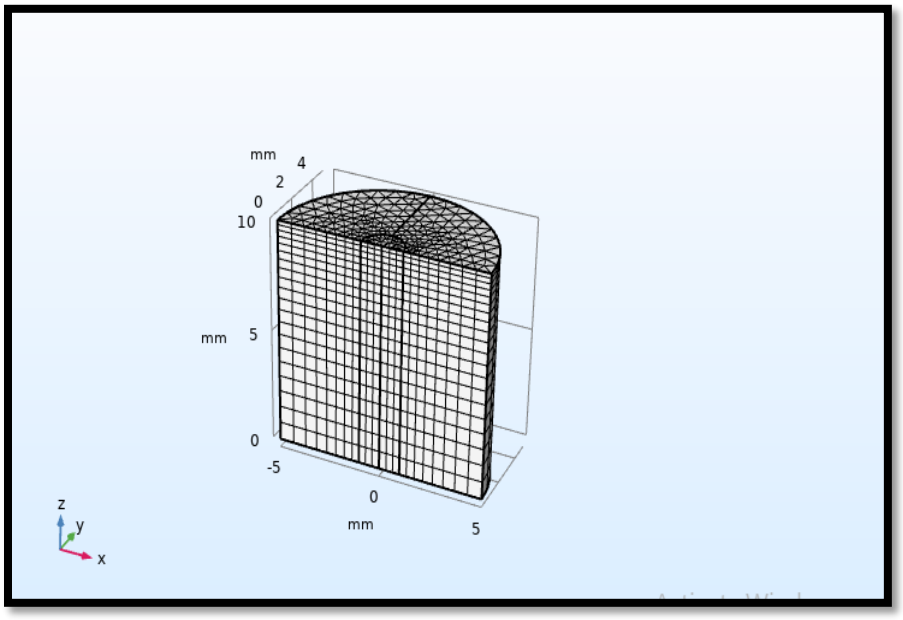


Figure (3-6) : structure of sample (geometrical mesh)

Part One : Experimental Part

(4-1) Introduction :

This chapter dealt with the results of the optical properties before and after irradiation of blood (healthy blood, anemia and thalassemia) using UV-visible spectrophotometers with their discussion , where a change in optical properties was observed after the irradiation process. On the other hand, this chapter also deals with the theoretical results that it was simulated using the COMSOL Multiphasic program .

(4-2) Optical properties of blood samples (Healthy, Anemia , Thalassemia) before Irradiation :

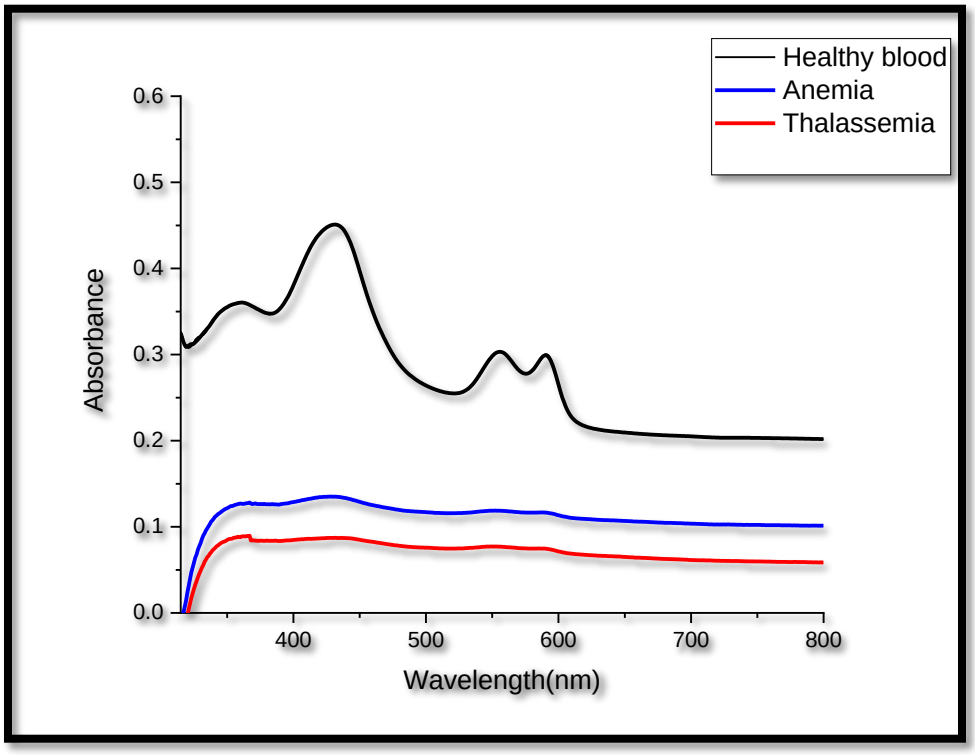
4-2-1 Optical properties :

A. Absorbance:

The absorption spectra of (healthy blood , anemia and thalassemia) before exposure to irradiation were studied using UV-Visible spectrophotometer , and the following are the results obtained from the study .

Figure (4-1) shows the absorption spectra of (healthy blood, anemia and thalassemia) before exposure to irradiation. Physically the absorption is the transformation of part of the energy for the incident radiation on the material , and this energy acquired by the atoms or molecules of material is either thermal or vibration .Absorption depends on several factors, including the properties of the material , the concentration of the absorbent particles as well as the wavelength of the incident radiation , when the concentration of the material increases , this results in an increase in absorption . It is noted from the figure that the absorption spectrum

of healthy blood appeared to have a clear absorption peak around wavelength (400nm) , while the absorption peaks in the anemia and thalassemia blood spectrum were very weak, and this due to increase concentration of absorbent molecules (Hemoglobin), so the absorption is higher in the case of healthy blood, while in the case of in case of anemia and thalassemia, they have poor absorption inside the sample due to the low concentration of the material .



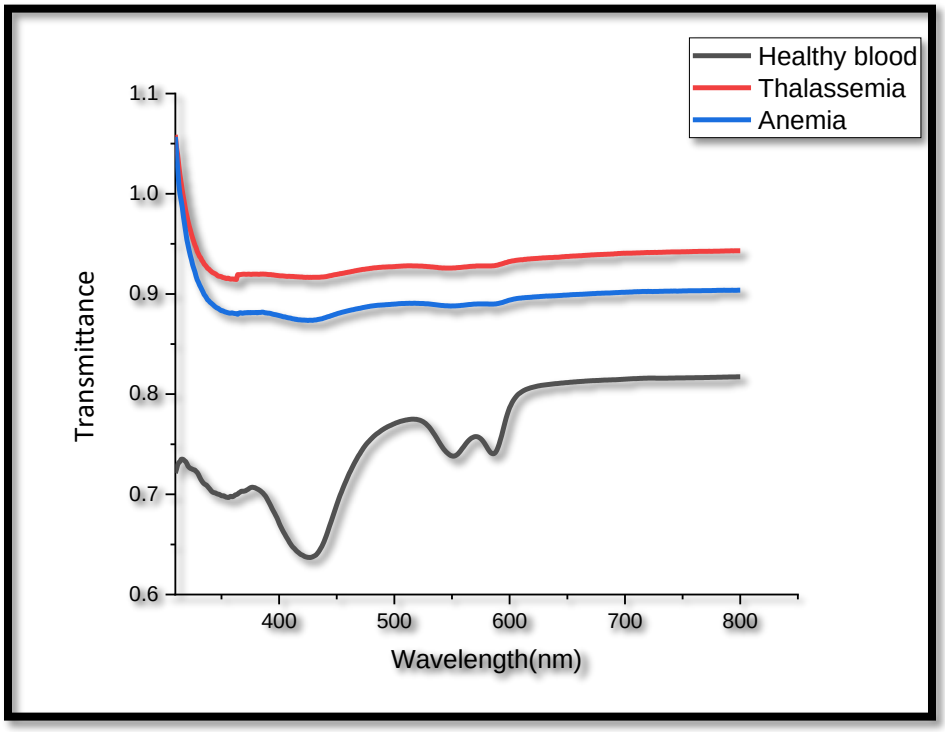
Figure(4-1) : Absorption spectra of (healthy blood, anemia and thalassemia) before exposure to irradiation

B. Transmittance:

The figure (4-2) states transmittance as a function of wavelength for (healthy blood , anemia and thalassemia) before exposure to irradiation . In physics a portion of the incident light ray at a specific wavelength passes through the sample. If the sample is transparent, it will come out not absorbed, and this is an ideal case.

Usually, it loses part of its energy inside the material due to its absorption in the sample and gradually weakens, and the part that was not absorbed comes out of the sample. The concept of transmittance is associated with the concept of absorption.

The transmittance to healthy blood decreases while blood of anemia and thalassemia increases because of increasing in absorbance by highly concentration of material (healthy blood) and decreased in material (blood with anemia and thalassemia) due to low concentration of material as well as high transmittance , that means the amount of light that successfully passes through the sample and comes out the other side , that is the more transparent material having high transmittance .

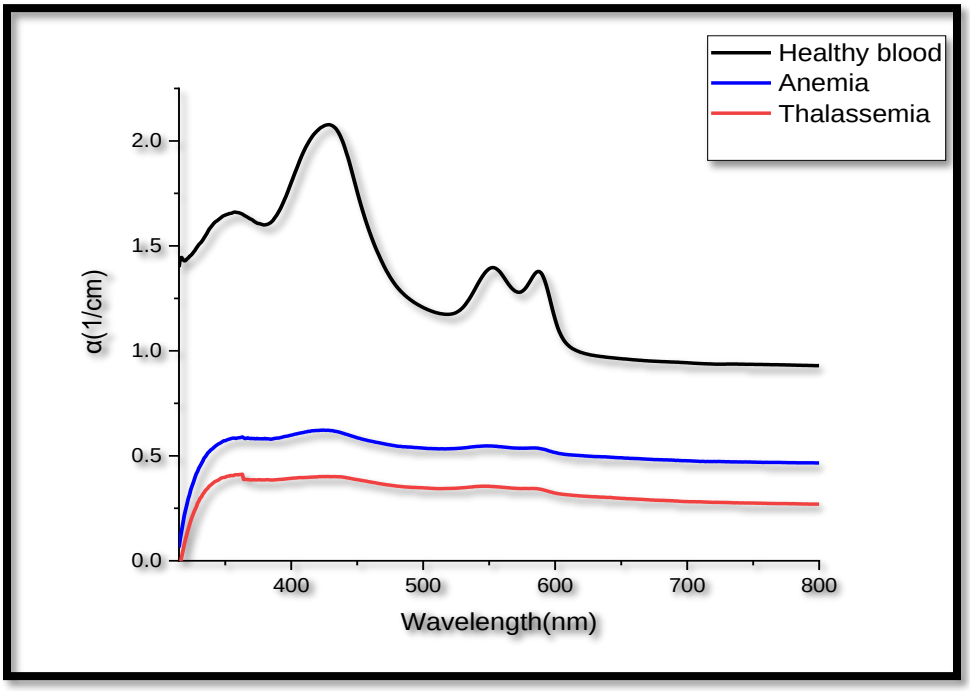


Figure(4-2) : Transmittance spectra of (healthy blood, anemia and thalassemia) before exposure to irradiation

4-2-2 Optical constants :

A. Absorption coefficient :

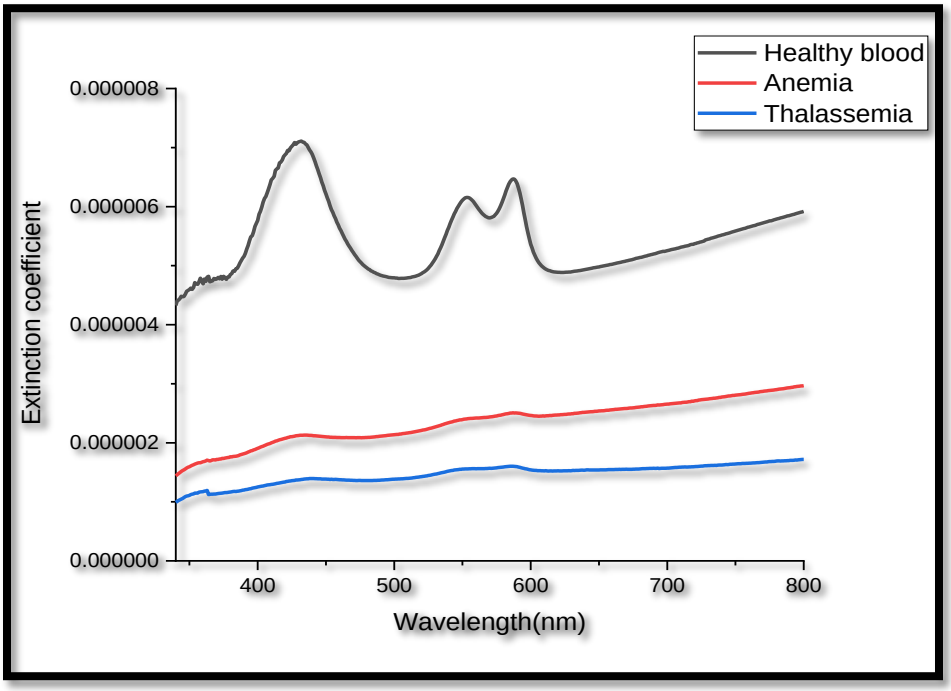
In general the absorption coefficient determines how far into a material light of a particular wavelength can penetrate before it is absorbed. In a material with a low absorption coefficient, light is only poorly absorbed, and if the material is thin enough, it will appear transparent to that wavelength. The absorption coefficient depends on the material and also on the wavelength of light which is being absorbed. The absorption coefficient spectrum in figure (4-3) for healthy blood having clear peak around wavelength (400 nm) due to chromospheres concentration (hemoglobin) of healthy blood while in anemia and thalassemia , the spectrum of absorption coefficient having weak peaks around wavelength (400 nm) because of the reduction in (hemoglobin) respectively .



Figure(4-3) : Absorption coefficient of (healthy blood, anemia and thalassemia) before exposure to irradiation

B. Extinction coefficient :

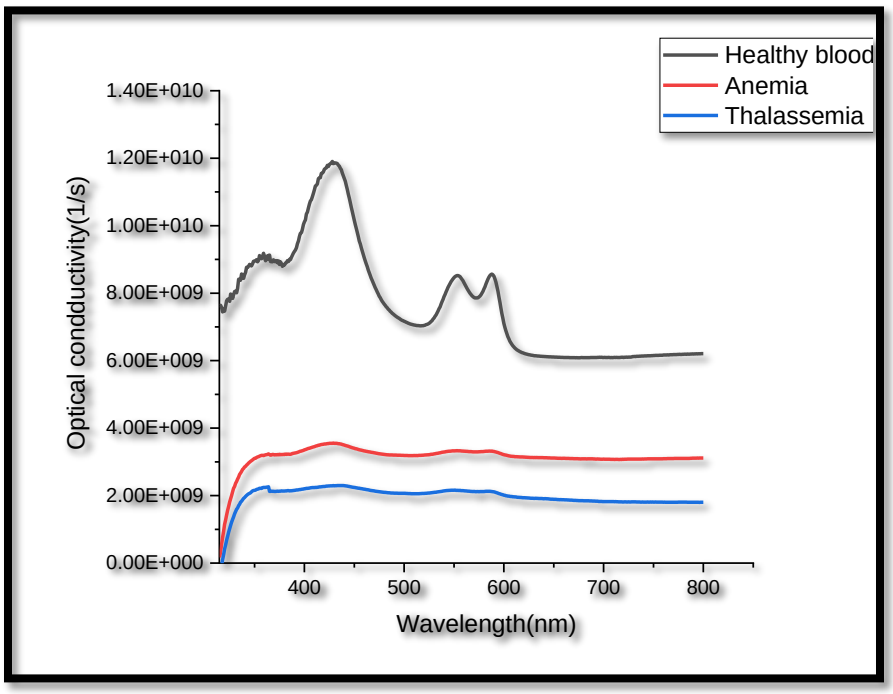
Figure (4-4) shows the spectrum of extinction coefficient for (healthy blood , anemia and thalassemia) . The extinction coefficient represent the amount of absorbed power when the electromagnetic radiation incident on samples , the amount of extinction coefficient depend on wavelength of incidence light and absorption coefficient of samples . The magnitude of extinction coefficient for (healthy blood sample) varying with wavelength of UV-VISBLE spectrophotometer, and increasing with increases of chromospheres concentration (hemoglobin) in healthy blood sample because it is responsible for absorbing the incident light , while in anemia and thalassemia samples the magnitude of extinction coefficient reduced because of decreases in chronophers concentration (hemoglobin).



Figure(4-4) : Extinction coefficient of (healthy blood, anemia and thalassemia) before exposure to irradiation

C. Optical conductivity:

In figure (4-5) of optical conductivity for (healthy blood, anemia and 3thalassemia) . The magnitude of optical conductivity changing with wavelength of light of UV-VISBLE spectrophotometer and increasing with healthy blood sample at higher magnitude and then decreases with samples of anemia and thalassemia respectively because of high concentration of absorbent molecules in the material (healthy blood) and low concentration of absorbent molecules in the material which results high optical conductivity in dense material and low optical conductivity in material with low density (low concentration of molecules) .



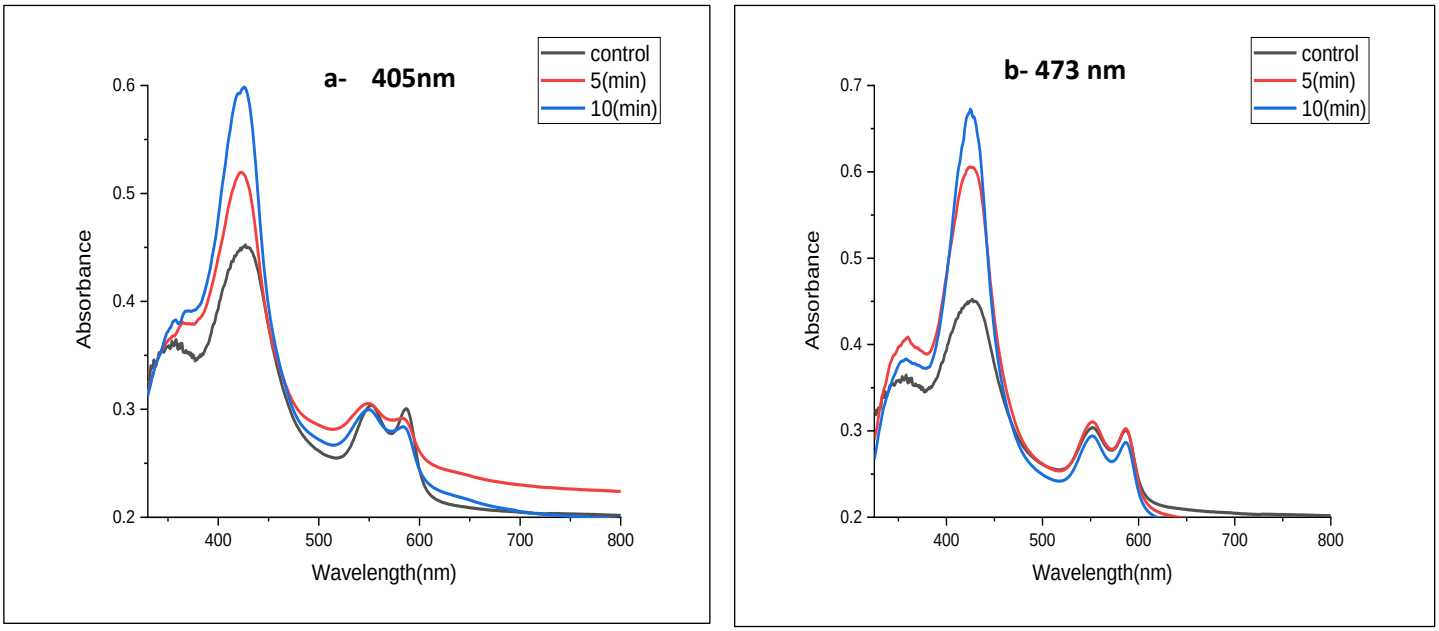
Figure(4-5) : Optical conductivity of (healthy blood, anemia and thalassemia) before exposure to irradiation

(4-3) Optical Properties of healthy blood after irradiation

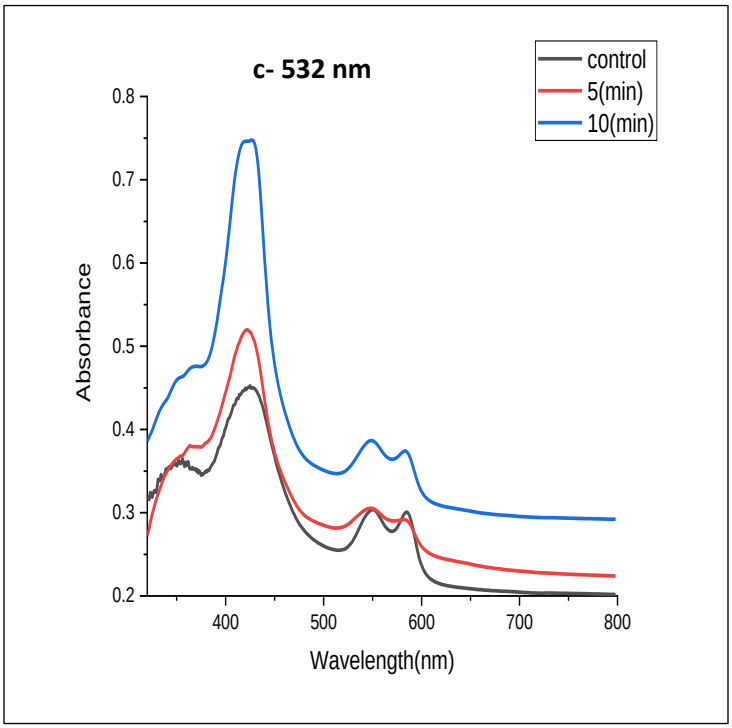
4-3-1 Optical properties:

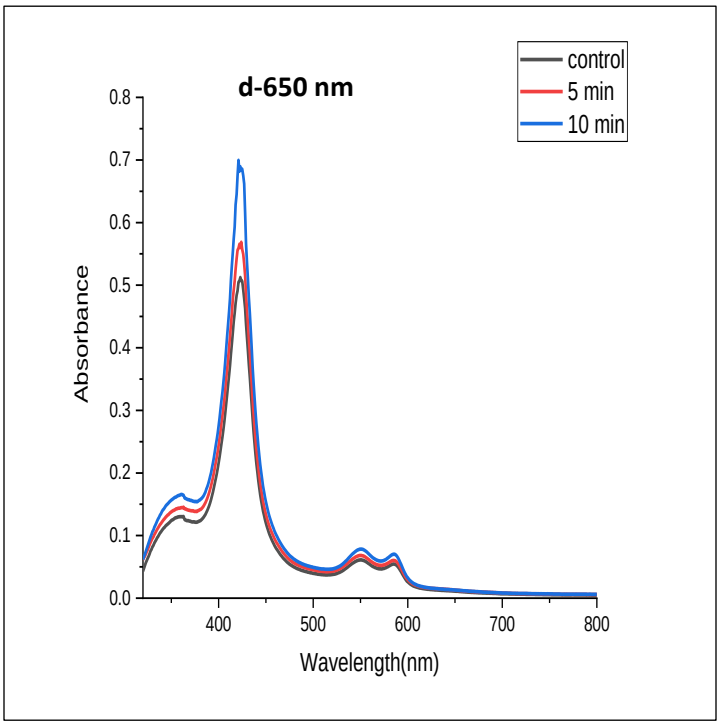
A. Absorbance :

Figure (4-6-A,B) shows the absorbance of samples after irradiation with (405 nm ,473nm,532nm,650 nm) with output power (20 mW) at different exposure time (5 min , 10 min) . the absorbance of healthy blood samples increased after irradiation with different wavelengths due to the interaction between laser and molecules of material (blood sample) and this means that increasing in the temperature of the medium because of transformation of energy from incident photons to the molecules of material , and then increases in the vibrational energy of material molecules. The excitation state in the molecules of medium by absorbing the energy of incident photon , which makes the medium temperature rise ,and thus this process plays an important role in determining some physical properties , like thermal conductivity .



Figure(4-6-A) : Absorbance of healthy blood after exposure to (a-405nm , b- 473 nm)

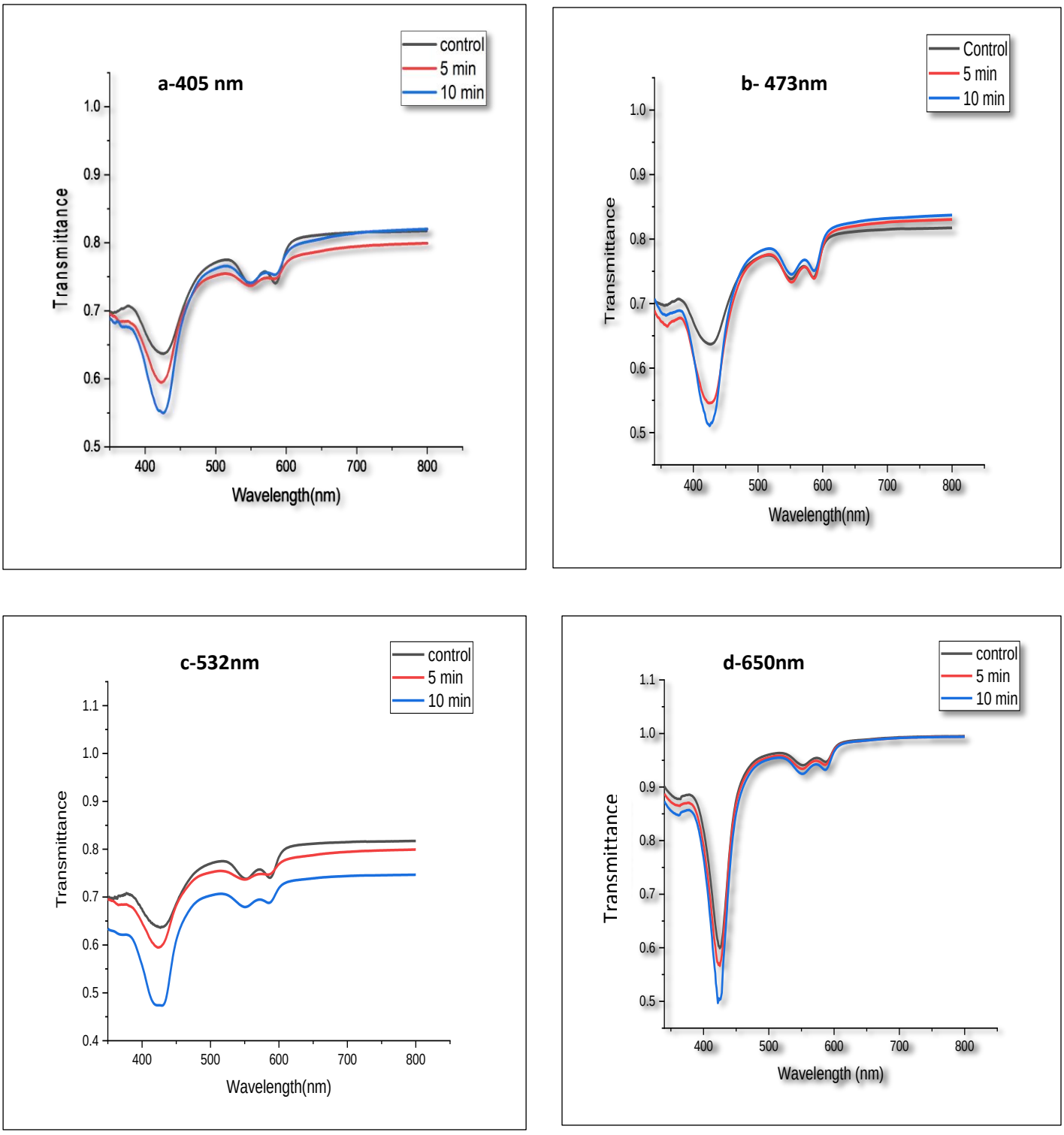




Figure(4-6-B) : Absorbance of healthy blood after exposure to (c-532nm , d- 650 nm)

B. Transmittance :

The transmittance of healthy blood sample before and after irradiation with wavelengths of laser (405 nm ,473nm, 532nm,650nm) with different exposure time (5min,10min) state in figure (4-7) . As the light strikes the molecules of sample , absorption , reflection and transmission took place , the transmission of laser light decreases gradually from the laser irradiation with exposure time (5 min) to the irradiation with exposure time (10 min) , that case produce small portion of light was transmitted and has highly absorption because of the increase in penetration of laser light in material with increasing the exposure time of laser beam between (5,10) minutes as a result the irradiation to human blood changes the ability to absorb and passage the light .



Figure(4-7) :Transmittance of healthy blood before and after exposure to (a-405nm,b-473nm,c-532nm,d-650nm)

4-3-2 Optical constants:

A. Absorption coefficient :

The absorption coefficient spectrum in figure (4-8-A,B) for healthy blood before and after irradiation with (405 nm ,473nm,532nm, 650nm).The thickness of thin film is (300nm) , where this film have higher peak around wavelength(400nm) for exposure time (10 min) and then decreases at exposure time (5 min) and control sample, the increase in absorption coefficient at the second time period of exposure time (10 min) came as a result of the increase in absorbance of the medium due to high concentration of molecules inside the medium and therefore the absorption elements in blood represented by hemoglobin absorb the energy of laser beam and more depth of penetration of the laser through the sample .

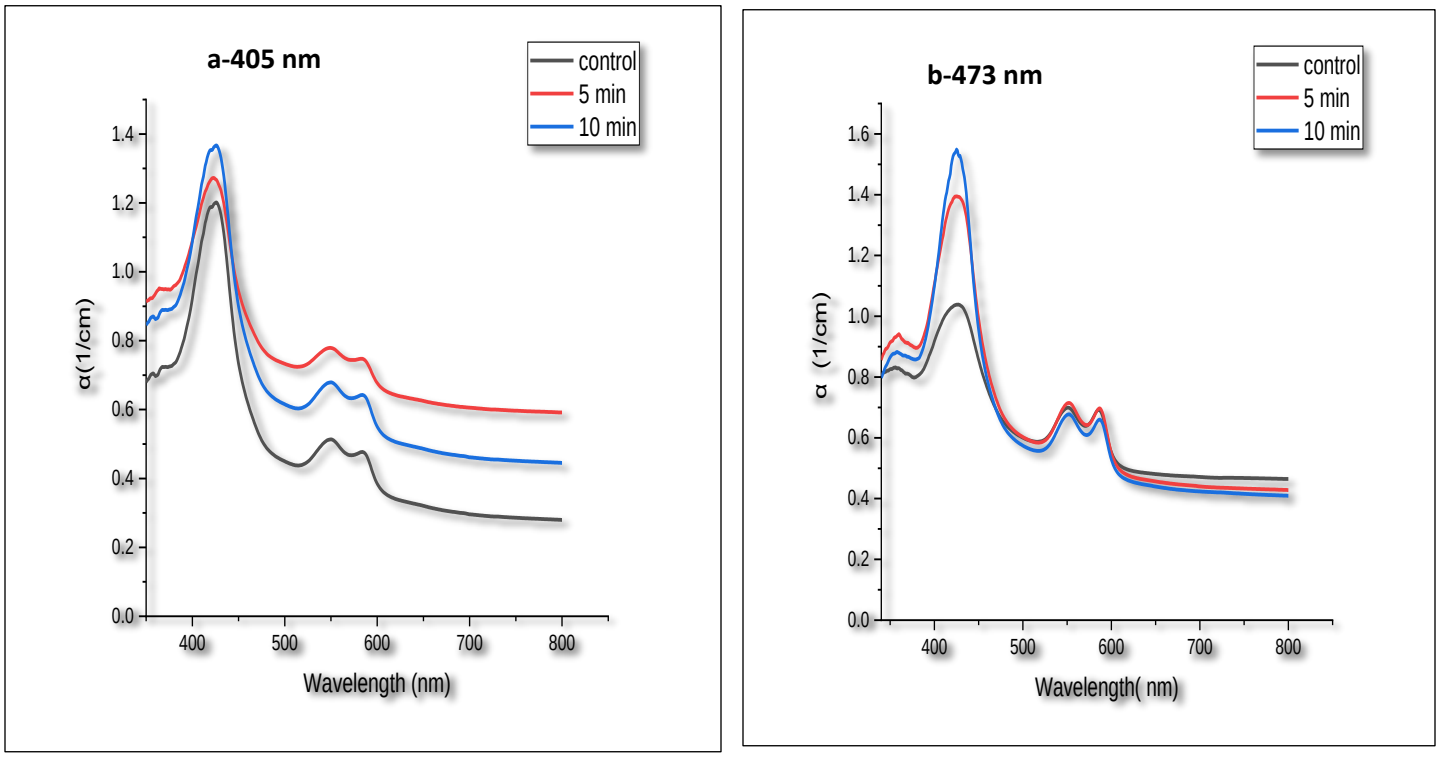


Figure (4-8-A) :Absorption coefficient of healthy blood before and after exposure to (a-405 nm ,b-473 nm)

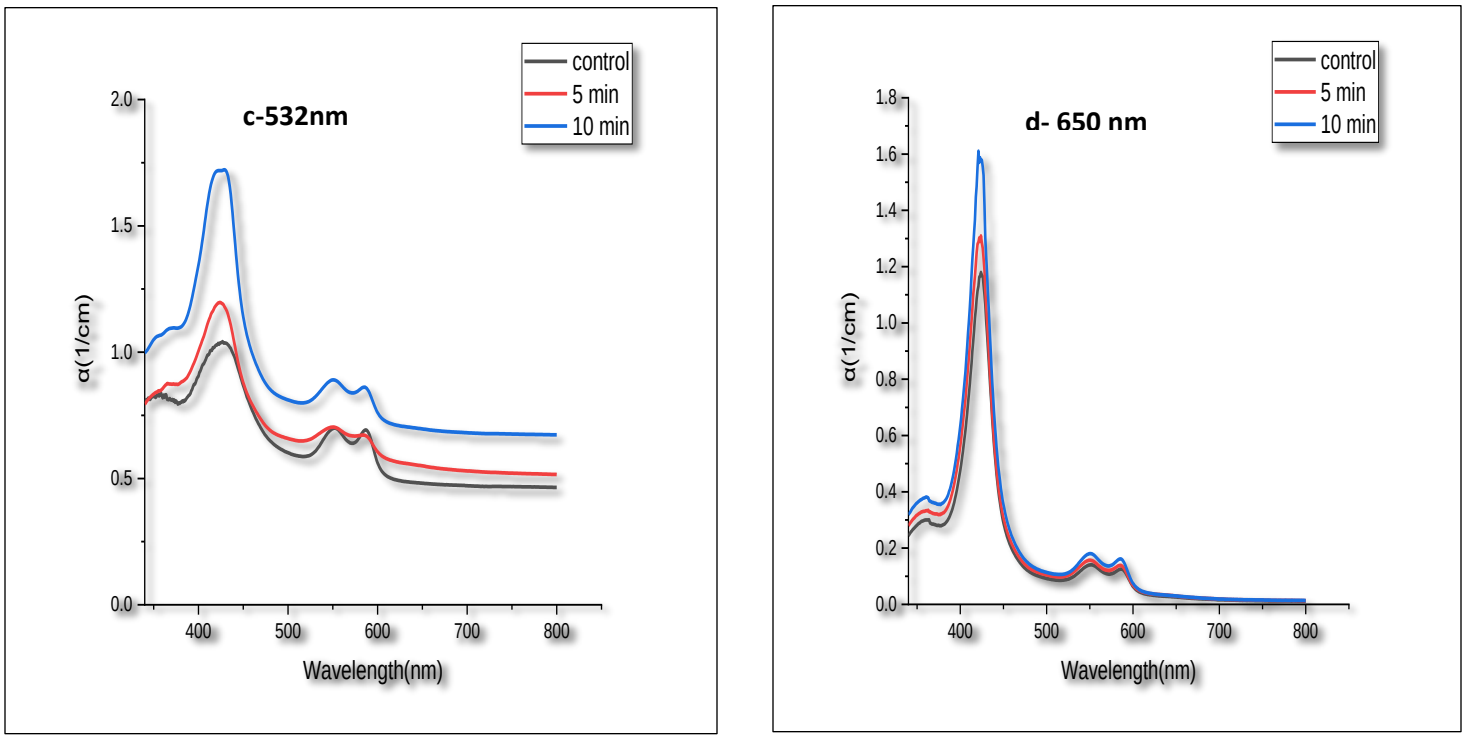


Figure (4-8-B) :Absorption coefficient of healthy blood before and after exposure to (c-532nm , d- 650nm)

B. Extinction coefficient:

The spectrum of extinction coefficient for healthy blood before and after irradiation with wavelengths (405 nm,473nm,532nm,650nm) showed in figure (4-9) . The extinction coefficient represent the amount of energy loss due to the interaction between incident laser beam and molecules of the medium , the amount of extinction coefficient depend on wavelength of incidence light and absorption coefficient of samples .

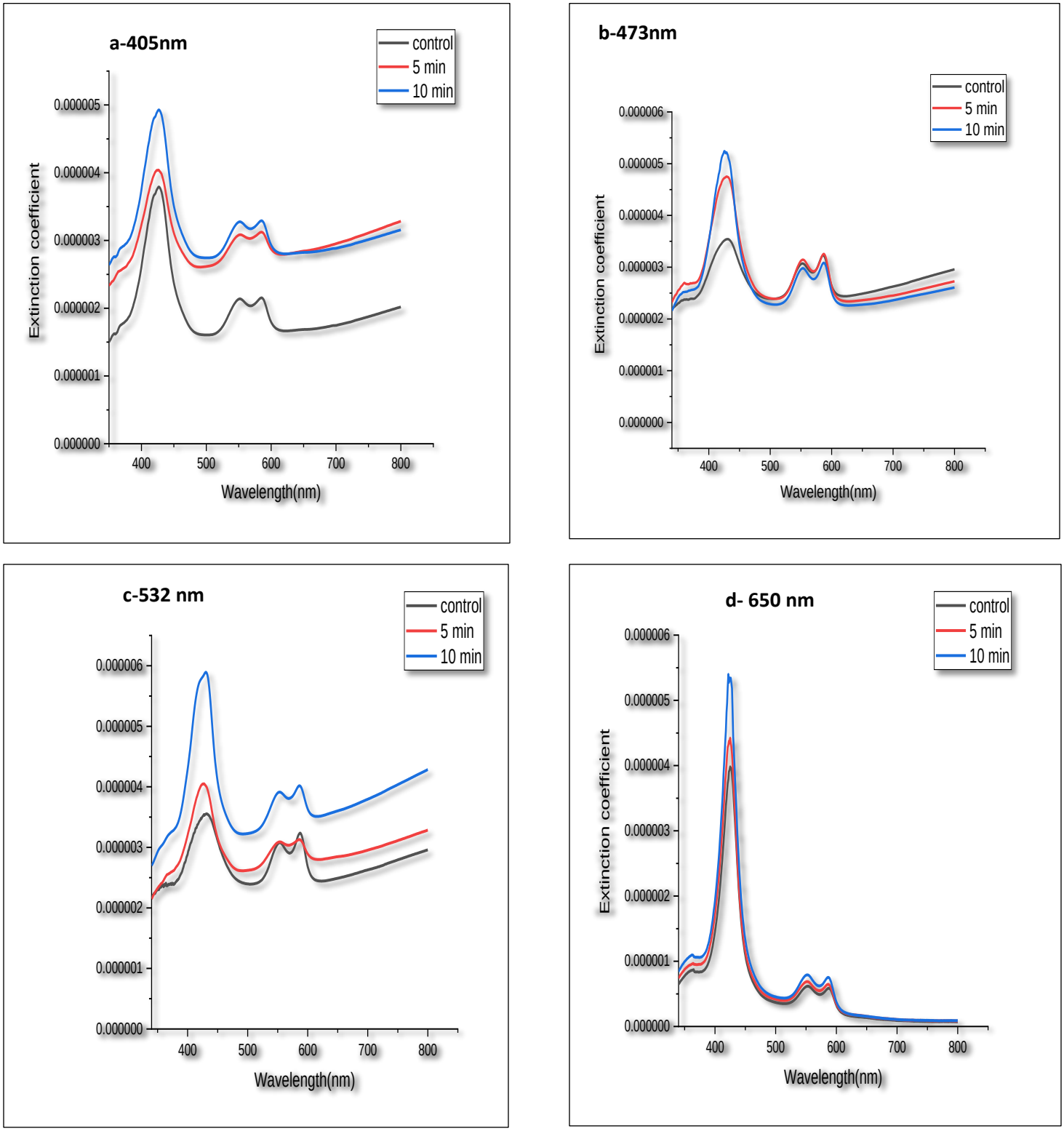


Figure (4-9) :Extinction coefficient of healthy blood before and after exposure to (a-405nm,b-473nm,c-532nm , d- 650nm)

C. Optical conductivity :

In figure (4-10-A,B) of optical conductivity for healthy blood sample before and after irradiation with wavelength (405 nm,473nm,532nm,650nm) . The magnitude of optical conductivity changing with time of laser exposer time in case of laser irradiation and increasing with healthy blood sample after irradiation with wavelength (405 nm ,473nm,532nm,650nm) at different exposure time (5 min and10min) . The change in the optical conductivity is correlated with the change in the absorption coefficient for all wavelengths used in the irradiation , because of the dependence of the optical conductivity on the absorption coefficient according to the mathematical relation (2-9) mentioned previously in chapter two.

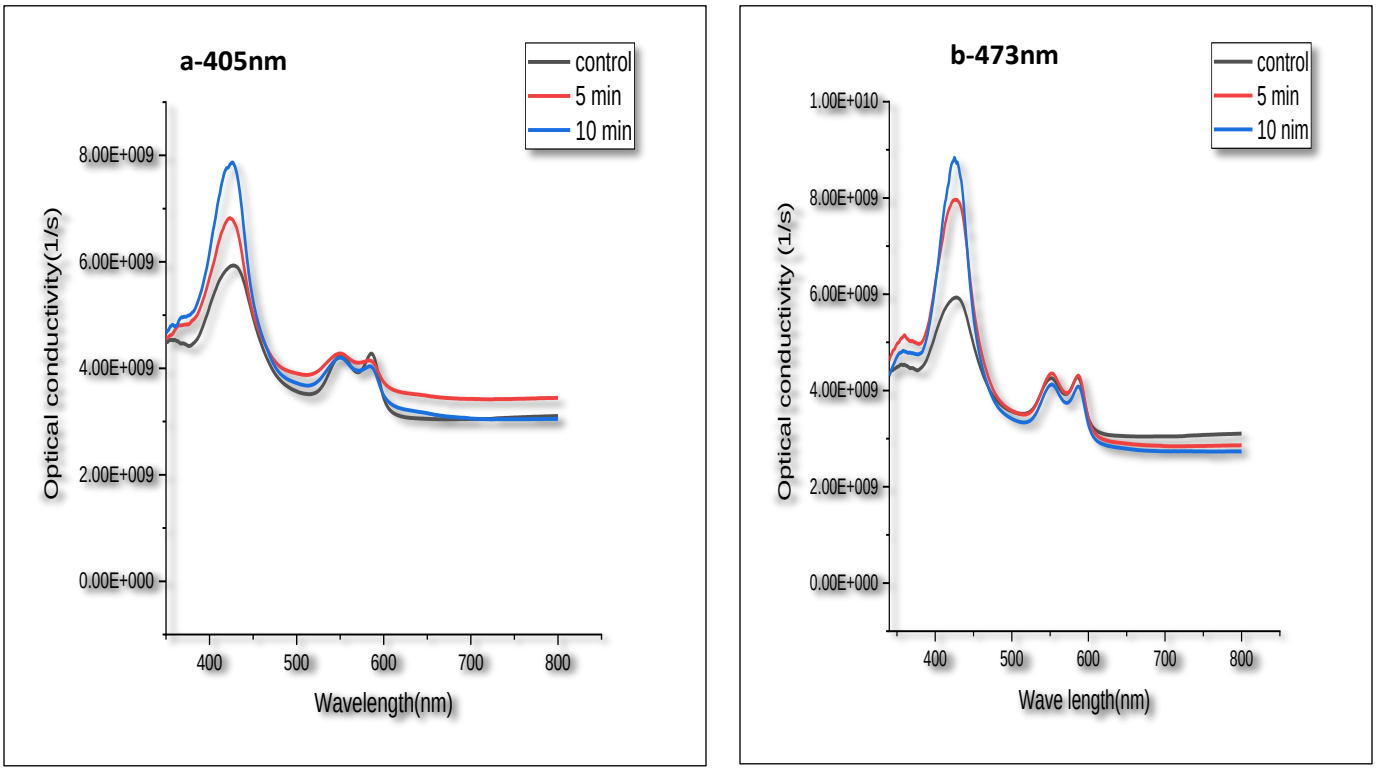


Figure (4-10-A) : Optical conductivity of healthy blood before and after exposure to (a-405 nm,b-473 nm)

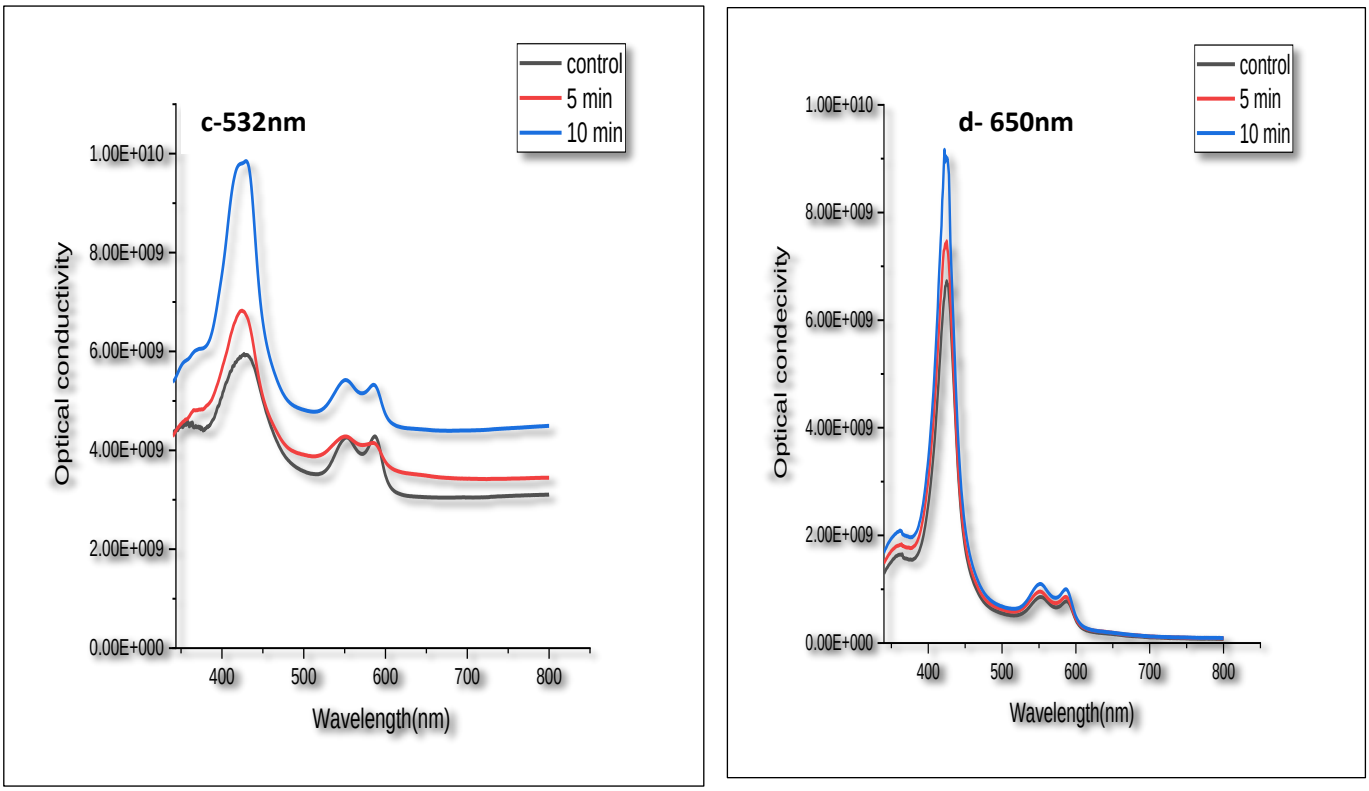


Figure (4-10-B) : Optical conductivity of healthy blood before and after exposure to (c-532 nm,d-650nm)

(4-4) Effect of laser irradiation on optical properties of healthy blood sample :

From the above calculating the optical properties of healthy blood before and after irradiation , where in this paragraph the results are compered .

In general ,from the results the absorption is increased when exposing different wavelengths of the laser at different exposure time (5, 10) minutes , this is due to the absorption properties of light by molecules and this properties depends on the molecular environment and mobility of chomophores. The absorption process provides information about chemical composition and structure of the cell , when the light strikes the molecule suffers (absorption , transmission and reflection) , the magnitude of absorption in the sample depend on concentration of absorption

component , when the component of absorption increase , absorption increased and the transmission decreased with small portion of reflection . The absorbed photon is exited to the another state and release the energy to achieve stability , this phenomena is important in effects in tissues . Absorption coefficient of the healthy blood sample slight increase after irradiation with different wavelengths of lasers that used , it is known that the absorption coefficient is the percentage decreases in energy radiation flux to a distance area with propagation direction of beam inside the sample , the absorption coefficient depend on the energy of incident photons and properties of sample , from results , when the laser beam passes through sample , the laser beam loses part of intensity by absorption of the sample and that's mean , the increases in absorption coefficient , even if it is slight , indicates the decrease in the flux of radiation energy as a result of the absorption in the sample by the chromophores , while extinction coefficient is the amount of attenuation in intensity of laser beam because of the interaction between laser beam and particles of sample , from results , the magnitude of extinction coefficient slightly increased and that's mean , the attenuation in intensity inside the sample is small .

(4-5) Optical Properties of blood with anemia after irradiation:

4-5-1 Optical properties :

A. Absorbance :

Figure (4-11) illustrate the relation between wavelength and absorbance for anemic blood sample before and after irradiation with (405 nm,473nm,532nm, 650nm) , from the results the absorbance of anemic blood sample after irradiation increased gradually between exposure times (5 , 10) minutes because the laser

radiation effect on optical properties of anemic blood , in general the absorbance increases when the concentration of absorbent elements in the sample increases , and this means that the increase in time of exposure to the laser will increase the aggregates of molecules of materials (red blood cells) , and thus increase the absorbance of the incident radiation by medium , and as a result of this interaction ,the temperature of medium increasing because of vibrational motion of molecules . The absorbance of healthy blood samples before irradiation with laser higher than absorbance of anemic blood sample before irradiation because the concentration of absorbent elements in healthy blood sample higher than anemic blood sample , thus, the concentration of hemoglobin (which is responsible for absorbing incident radiation) , is higher in healthy blood sample than anemic blood sample . The irradiation with laser radiation causes an increase in absorption in healthy blood sample and anemic blood sample at different exposure time (5 , 10) minuets due to the accumulation of red blood cells , thus , the absorbance increases after irradiation with laser radiation .

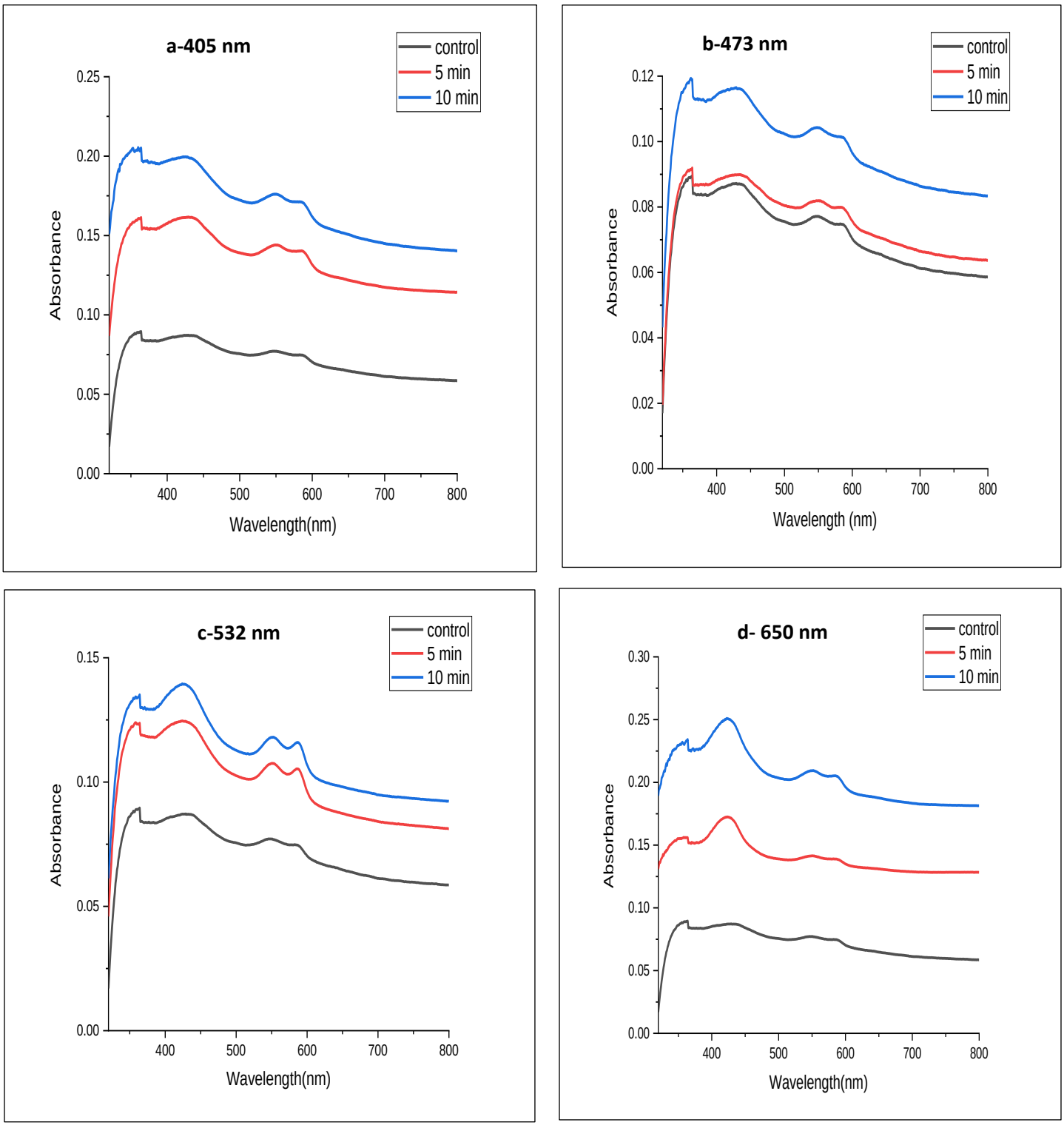


Figure (4-11) : Absorbance of blood with anemia before and after exposure to (a-405 nm,b-473nm,c-532nm,d-650nm)

B. Transmittance

The transmittance of anemic blood sample before and after irradiation with wavelength of laser (405 nm ,473nm,532nm,650 nm) shows in figure (4-12-A,B) .From the results the transmission of laser light decreases gradually from the laser irradiation with exposure time (5 min) to the irradiation with exposure time (10 min) and has higher value with samples that non- irradiated , that case produce small portion of light was transmitted and has highly absorption because of the increase in concentration of absorber elements as a result the irradiation to human blood changes the ability to absorb and passage the light .

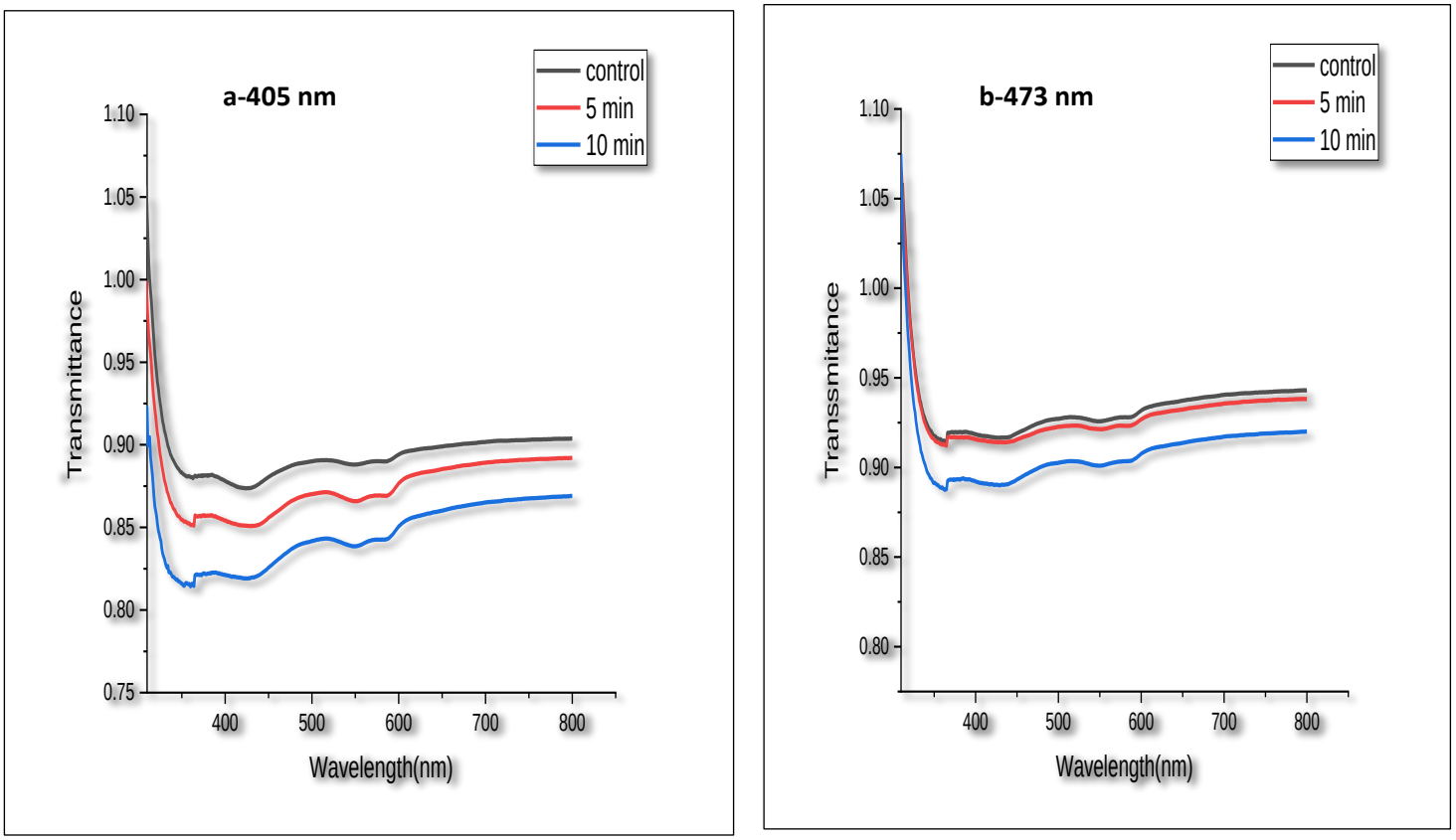


Figure (4-12-A) : Transmittance of blood with anemia before and after exposure to (a-405 nm, b-473nm)

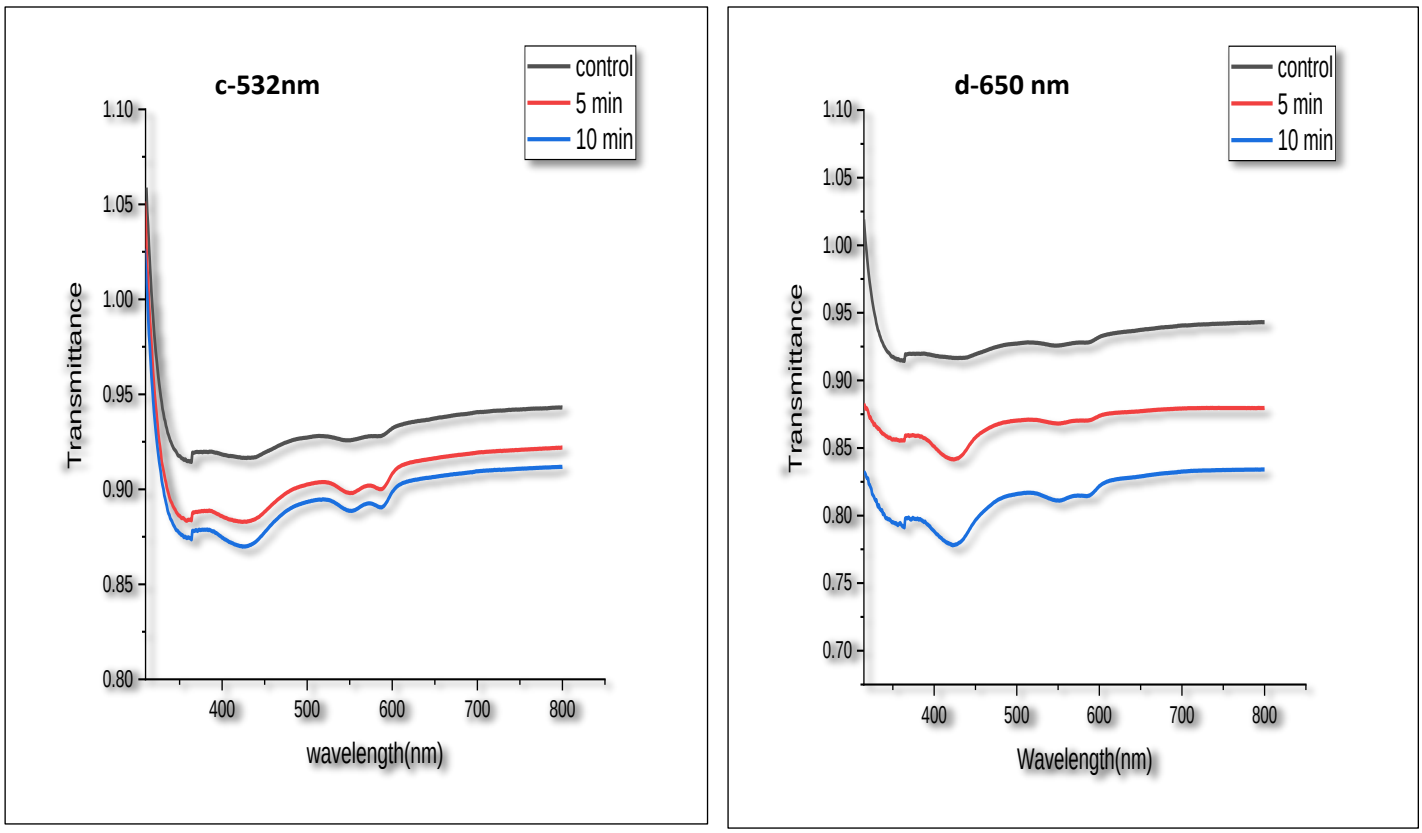


Figure (4-12-B) : Transmittance of blood with anemia before and after exposure to(405nm)

4-5-2 Optical constants

A. Absorption coefficient :

The absorption coefficient spectrum in figure (4-13) for anemic blood samples before and after irradiation with (405 nm,473nm,532nm,650nm) . The spectrum of absorption coefficient having variable magnitude between samples before and after irradiation with wavelengths .In general the material that have high absorbance by high concentration of molecules of material which results high value of absorption coefficient. The material with low concentration of molecules as a results low absorption and small value of absorption coefficient with high transmittance.

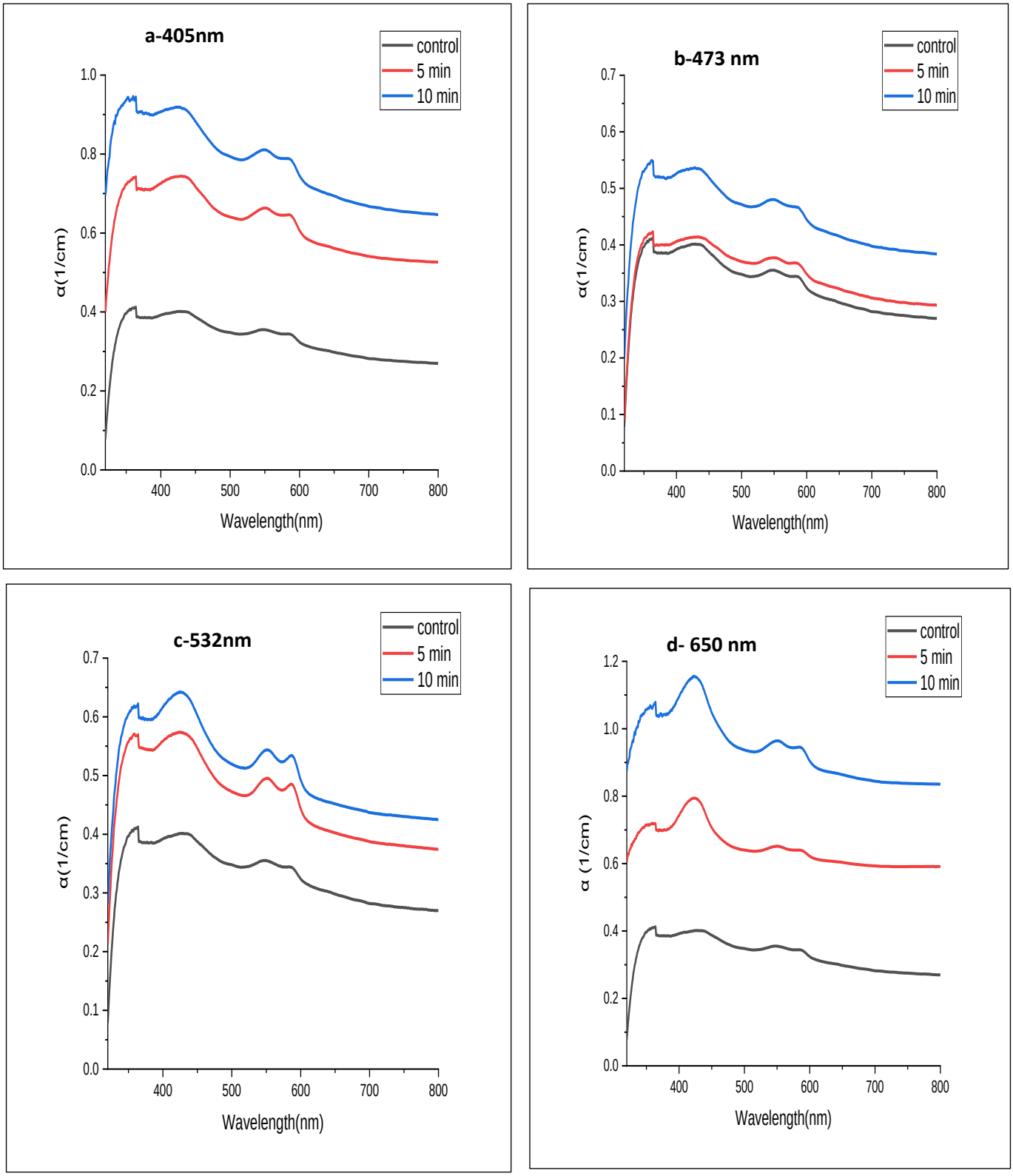


Figure (4-13) : Absorption coefficient of blood with anemia before and after exposure to(a-405 nm , b-473nm ,c-532nm , d-650nm)

B. Extinction coefficient :

The spectrum of extinction coefficient for anemic blood before and after irradiation with wave length (405 nm ,473nm,532nm,650nm) showed in figure (4-14-A,B) . The extinction coefficient represent the amount of absorbed energy when the electromagnetic radiation incident on samples , the amount of extinction coefficient depend on wavelength of incidence light and absorption coefficient of samples . The magnitude of extinction coefficient for anemic blood sample before and after irradiation with laser wavelengths was increased gradually in the range of wavelength (300 -800) nm .

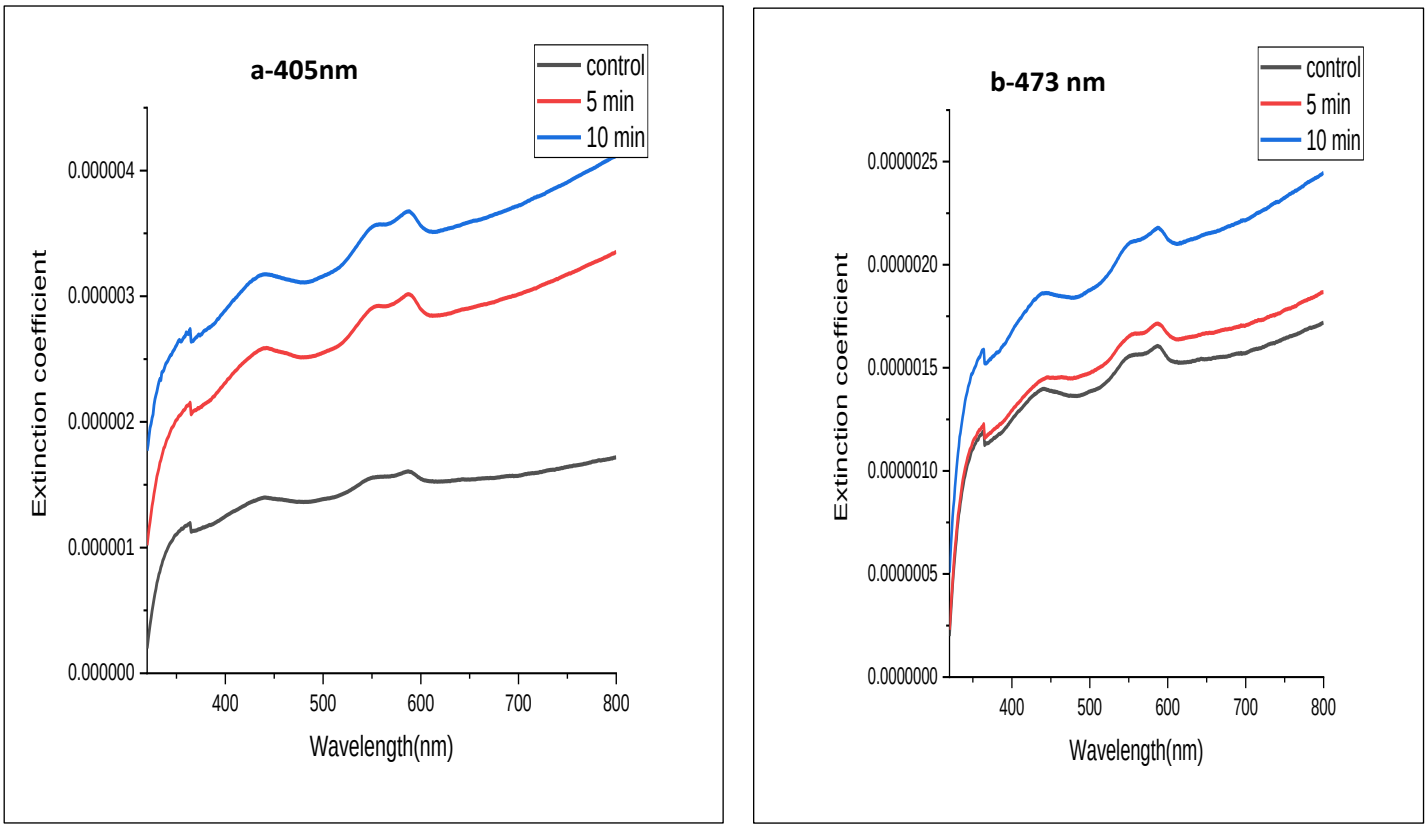


Figure (4-14-A) : Extinction coefficient of blood with anemia before and after exposure to (a-405 nm ,b-473nm)

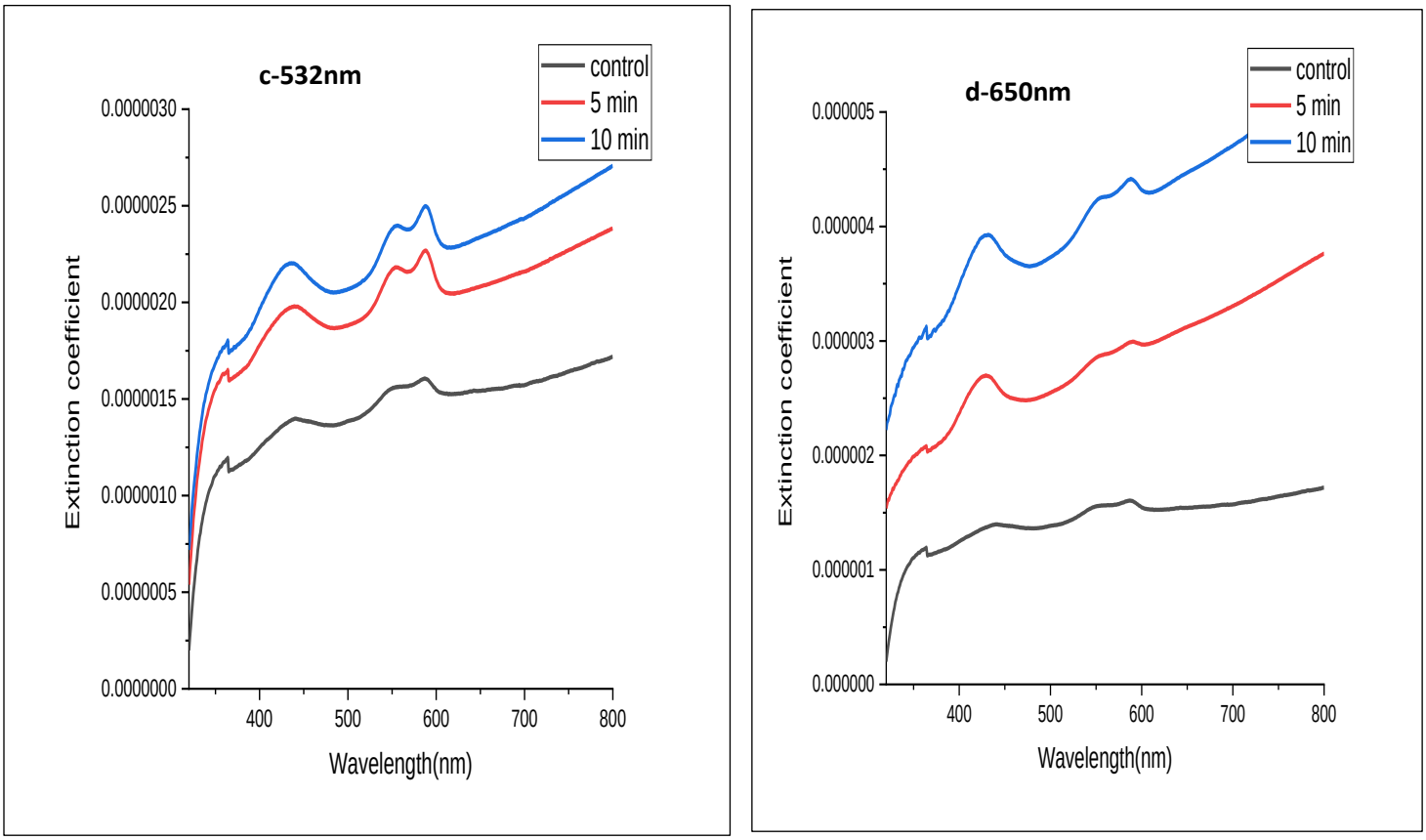


Figure (4-14-B) : Extinction coefficient of blood with anemia before and after exposure to (c-532 nm ,d-650nm)

C. Optical conductivity :

In figure (4-15) of optical conductivity for anemic blood sample before and after irradiation with wavelength (405 nm ,473nm,532nm,650nm) . The magnitude of optical conductivity changing with time of laser exposer time in case of laser irradiation and increasing with anemic blood sample after irradiation with wavelength (405 nm,473nm,532nm,650nm) at different exposure time (5 min and10min) with variable value and then decreases with samples of anemic blood before irradiation with laser beam.

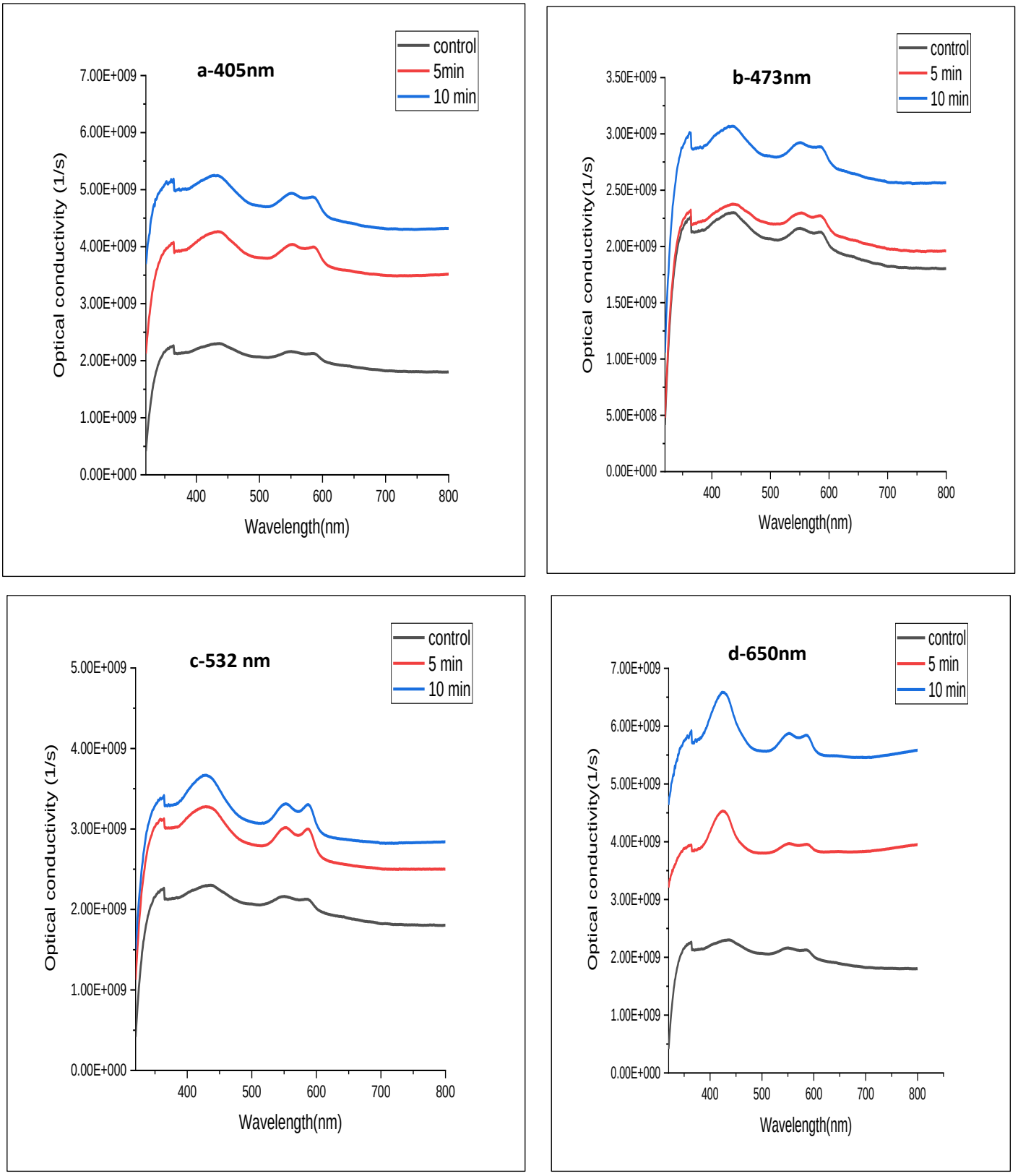


Figure (4-15) : Optical conductivity of blood with anemia before and after exposure to (a-405 nm,b-473nm,c-532nm,d-650nm)

(4-6) Effect of laser irradiation on optical properties of anemic blood sample :

The calculating the optical properties for anemic blood before and after irradiation were illustrated , where in this paragraph the results are compered .

Generally , from the results the absorption was increased when exposing different wavelengths of the laser at different exposure time (5, 10) minutes , this is due to the absorption properties of light by molecules and this properties depends on the molecular environment and mobility of chomophores. The blood samples with anemia suffers from a low number of red blood cell and therefore a low number of absorption elements (chromophores) . In using of laser radiation with wavelength (473 nm) , the absorption after (5 min) very close to the spectrum of anemic samples without irradiation (control sample) , that's mean the irradiation with (473 nm) has little effect after (5 min) of exposure and then absorbance rises when it reaches to the time of exposure (10 min) . The absorption process provides information about chemical composition and structure of the cell , when the light strikes the molecule suffers (absorption , transmission and reflection) , the magnitude of absorption in the sample depend on concentration of absorption component , when the component of absorption increase , absorption increased and the transmission decreased with small portion of reflection . The absorbed photon is exited to the another state and release the energy to achieve stability , this phenomena is important in effects in tissues . Absorption coefficient of the anemic blood samples increase after irradiation with different wavelengths of lasers that used , it is known that the absorption coefficient is the percentage decreases in energy radiation flux to a distance area with propagation direction of beam inside the sample , the absorption coefficient depend on the energy of incident photons and properties of sample , from results , when the laser beam passes through sample , the laser beam loses part of

intensity by absorption of the sample and that's mean , the increases in absorption coefficient , indicates the decrease in the flux of radiation energy as a result of the absorption in the sample by the chromophores , while extinction coefficient is the amount of attenuation in intensity of laser beam because of the interaction between laser beam and particles of sample , from results , the magnitude of extinction coefficient increased and that's mean , the attenuation in intensity inside the sample is small .

(4-7) Optical Properties of blood with thalassemia after irradiation:

4-7-1 Optical properties :

A. Absorbance :

The spectrum of absorbance for blood with thalassemia before and after irradiation with (405nm, 473nm,532nm,650nm) states in figure (4- 16-A,B) . The absorbance of blood with thalassemia before irradiation (control sample) decreases compered with healthy blood before irradiation because the blood with thalassemia can not make enough hemoglobin and red blood cells are nearly empty of hemoglobin and the concentration of absorbent elements (hemoglobin) decreases in blood with thalassemia compered with the absorbance of healthy blood, where the concentration of absorbent elements is high , and this explains the high absorbance in case of healthy blood before irradiation (control sample) . The absorption of blood with thalassemia after irradiation with (405 nm, 473nm,532nm,650nm) at different times of exposure (5 min , 10 min) increased compered with samples of healthy blood and blood samples with anemia after irradiation at different times of exposure because of the effect of the laser on the blood in all cases , which worked

to create aggregation between RBCs and thus increase the concentration of absorption elements (hemoglobin) in all cases (healthy blood , blood with anemia , and blood with thalassemia) and this explains the increase in absorbance after irradiation in all cases .

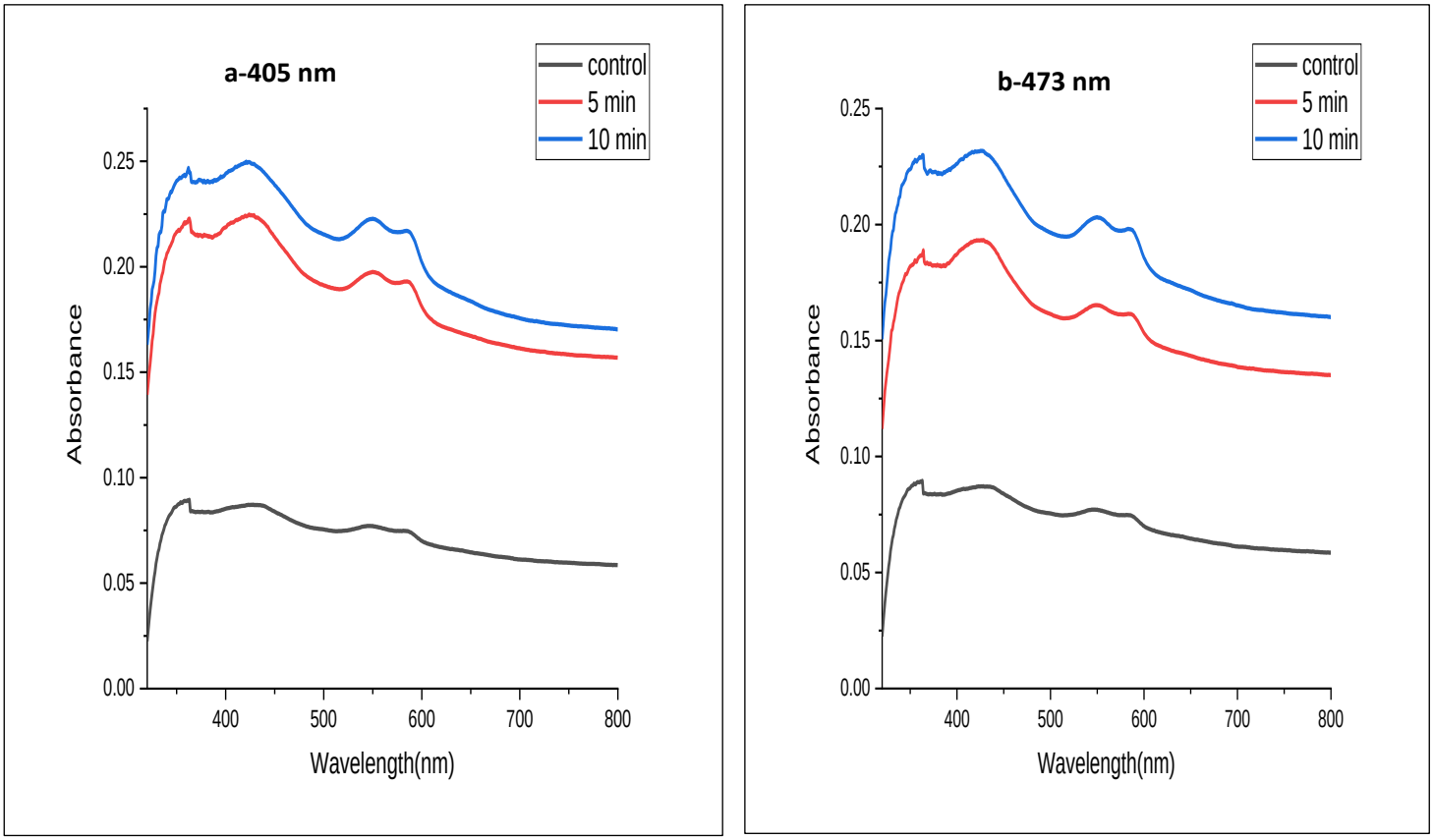


Figure (4-16-A) : Absorbance of blood with thalassemia before and after exposure to (a-405 nm,b-473nm)

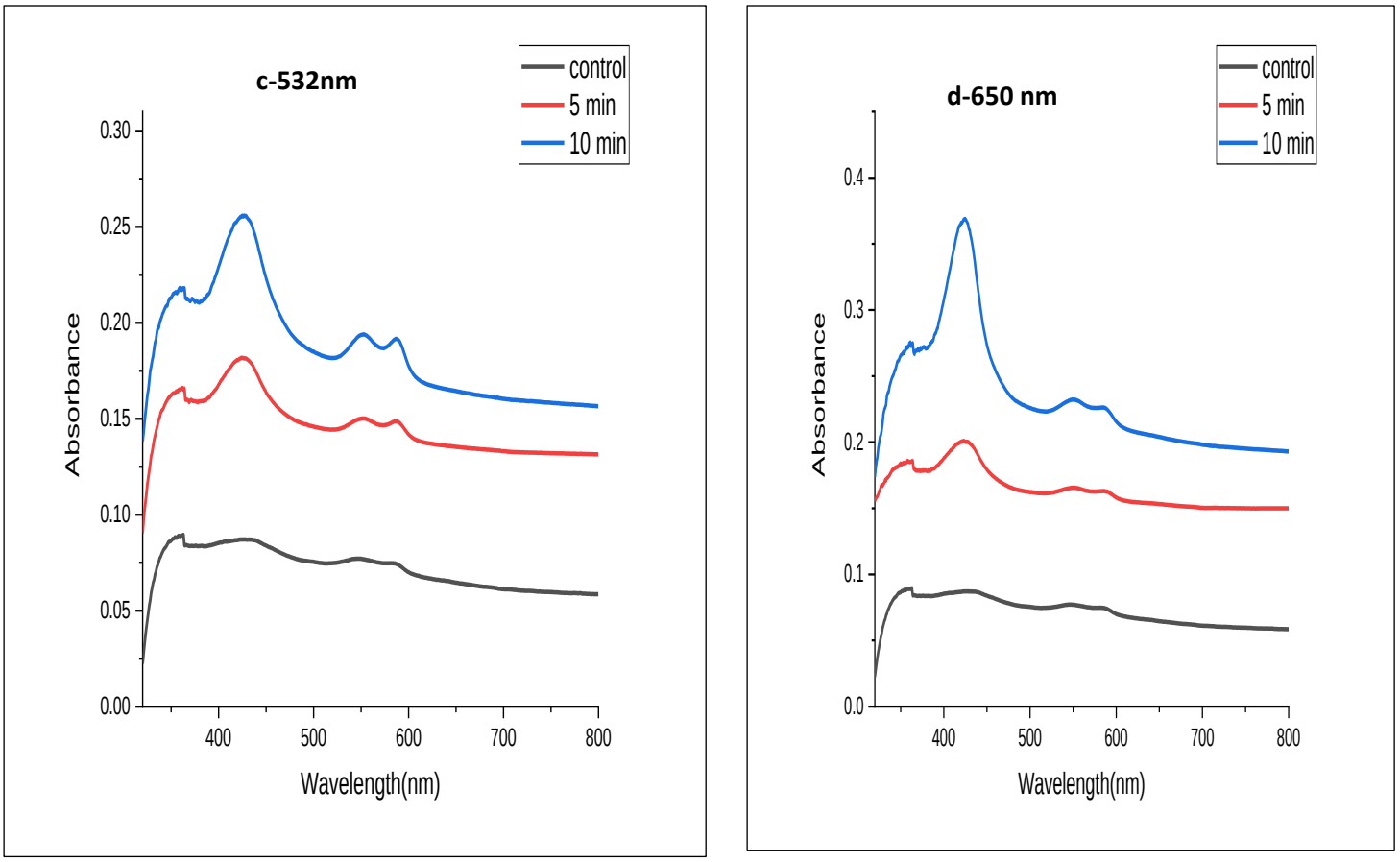


Figure (4-16-B) : Absorbance of blood with thalassemia before and after exposure to (c-532 nm,d-650nm)

B. Transmittance:

Figure (4-17) illustrate the transmission of blood with thalassemia before and after irradiation with (405 nm) .Generally transmittance means the passage of a portion for an incident light at a specific wavelength through a sample . The concept of transmittance is associated with the concept of absorption , whereby the absorption means the absorption by sample of a portion incident light at specific wavelength , the transmittance of blood with thalassemia decreased at (419 nm) after irradiation with (405 nm) compered with samples before irradiation (control sample) because of absorption of samples after irradiation was increased .

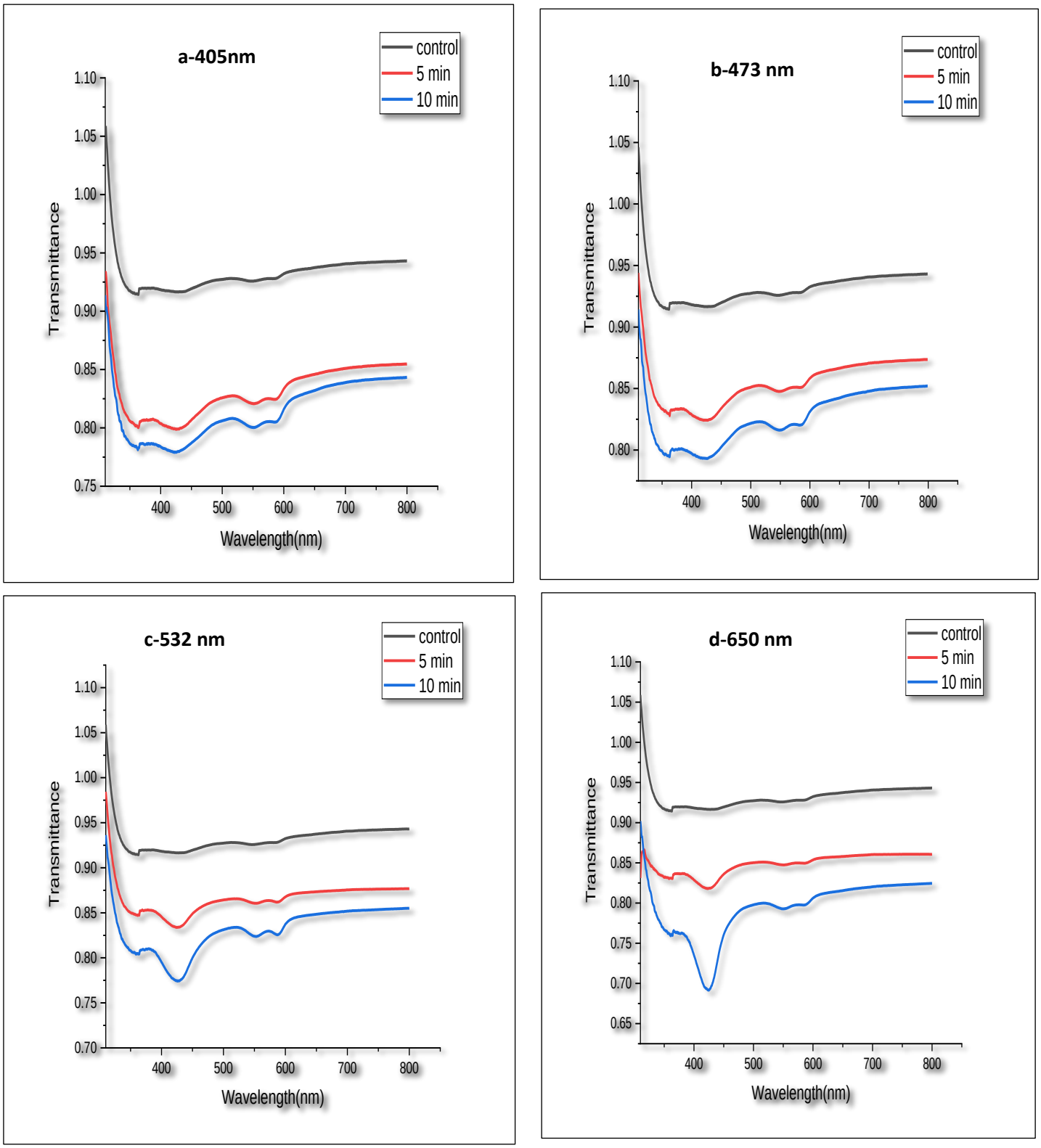


Figure (4-17) :Transmittance of blood with thalassemia before and after exposure to (a-405nm,b-473nm,c-532nm,d-650nm)

4-7-2 Optical constants :

A. Absorption coefficient :

Figure (4-18) shows the absorption coefficient of blood samples with thalassemia before and after irradiation with (405 nm,473nm,532nm,650nm) , the magnitude of absorption coefficient increases after irradiation with deferent wavelengths at both exposure times (5min , 10 min) and this case similar to both cases of blood samples (healthy samples and anemic samples) ,the absorption coefficient determines how far into a material light of a particular wavelength can penetrate before it is absorbed. In a material with a low absorption coefficient, light is only poorly absorbed, and if the material is thin enough, it will appear transparent to that wavelength. The absorption coefficient depends on the material and also on the wavelength of light which is being absorbed, the lower value of absorption coefficient for control sample before irradiation mean the blood sample with thalassemia is poorly absorber because of the low concentration of absorbent elements (hemoglobin).

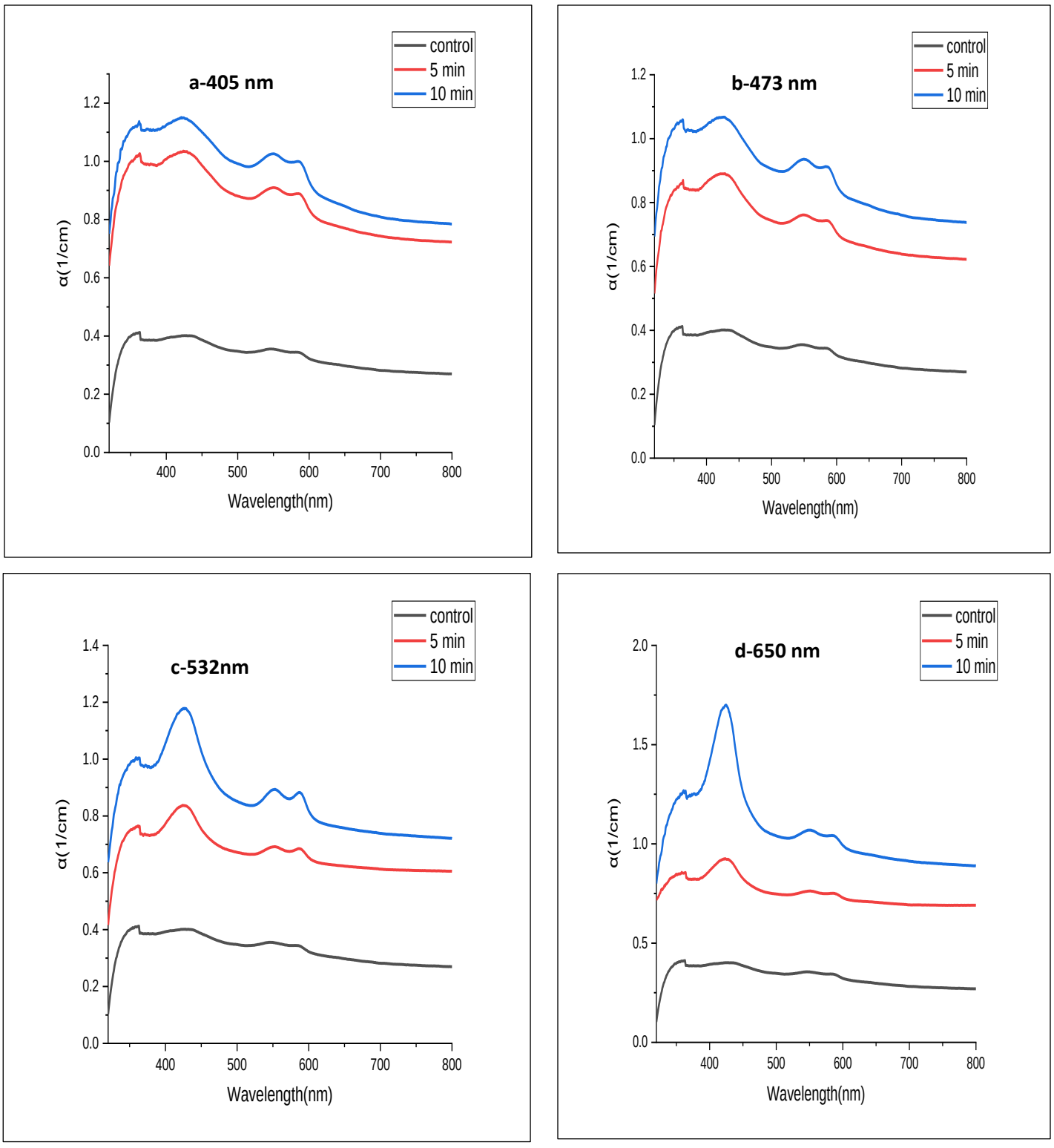


Figure (4-18) :Absorption coefficient of blood with thalassemia before and after exposure to(a-405nm,b-473nm,c-532nm,d-650nm)

B. Extinction coefficient :

Figure (4-19) show the variation of extinction coefficient with wavelength for blood with thalassemia before and after irradiation with wavelengths (405nm,473nm,532nm,650nm) . It's clear from these figures that the value of extinction coefficient increases with wavelength for cases before and after irradiation , hence , high value of extinction coefficient in lower wavelength range show these materials are non-transparent in this range. The extinction coefficient represent the amount of absorbed power when the electromagnetic radiation incident on samples , the amount of extinction coefficient depend on wavelength of incidence light and absorption coefficient of samples . The magnitude of extinction coefficient for blood with thalassemia samples before and after irradiation with laser wavelengths (405 nm,473nm,532nm,650nm) was increased gradually in the range of wavelength (300 -800) nm and this case similar to case of extinction coefficient for samples (healthy blood , anemic blood) after irradiation with (405 nm,473nm,532nm) .

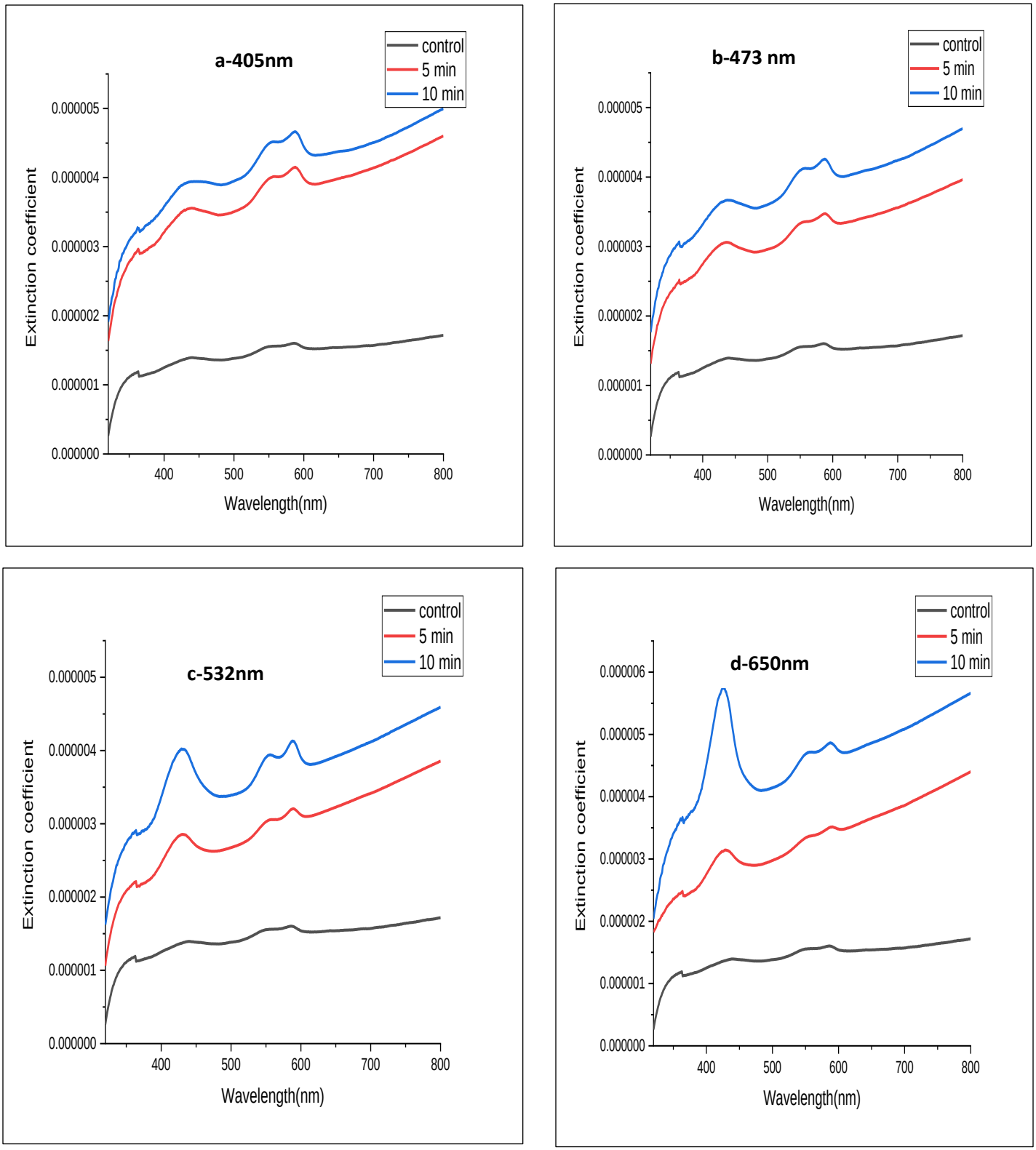


Figure (4-19) :Extinction coefficient of blood with thalassemia before and after exposure to (a-405nm,b-473nm,c-532nm,d-650nm)

C. Optical conductivity :

The optical conductivity for blood with thalassemia sample before and after irradiation with wavelength (405 nm,473nm,532nm,650nm) illustrate in figure (4-20-A,B) . The magnitude of optical conductivity changing with wavelength at different time of laser exposer in case of laser irradiation and increasing for blood samples with thalassemia after irradiation with wavelengths (405 nm,473nm,532nm,650nm) at different exposure time (5 min and10min) with variable value and then decreases for samples of blood with thalassemia before irradiation with laser beam.

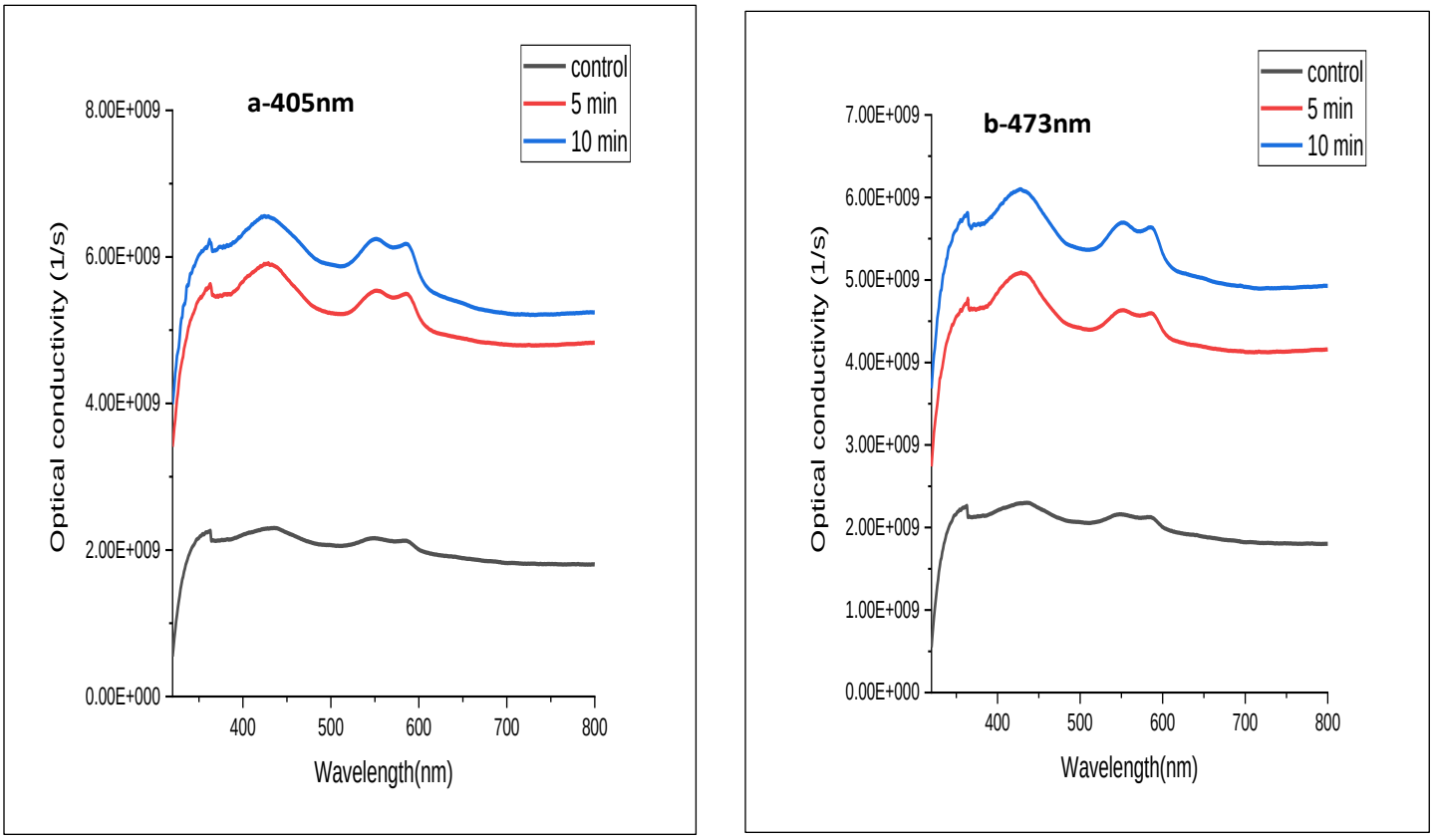


Figure (4-20-A) :Optical conductivity of blood with thalassemia before and after exposure to(a-405nm , b-473nm)

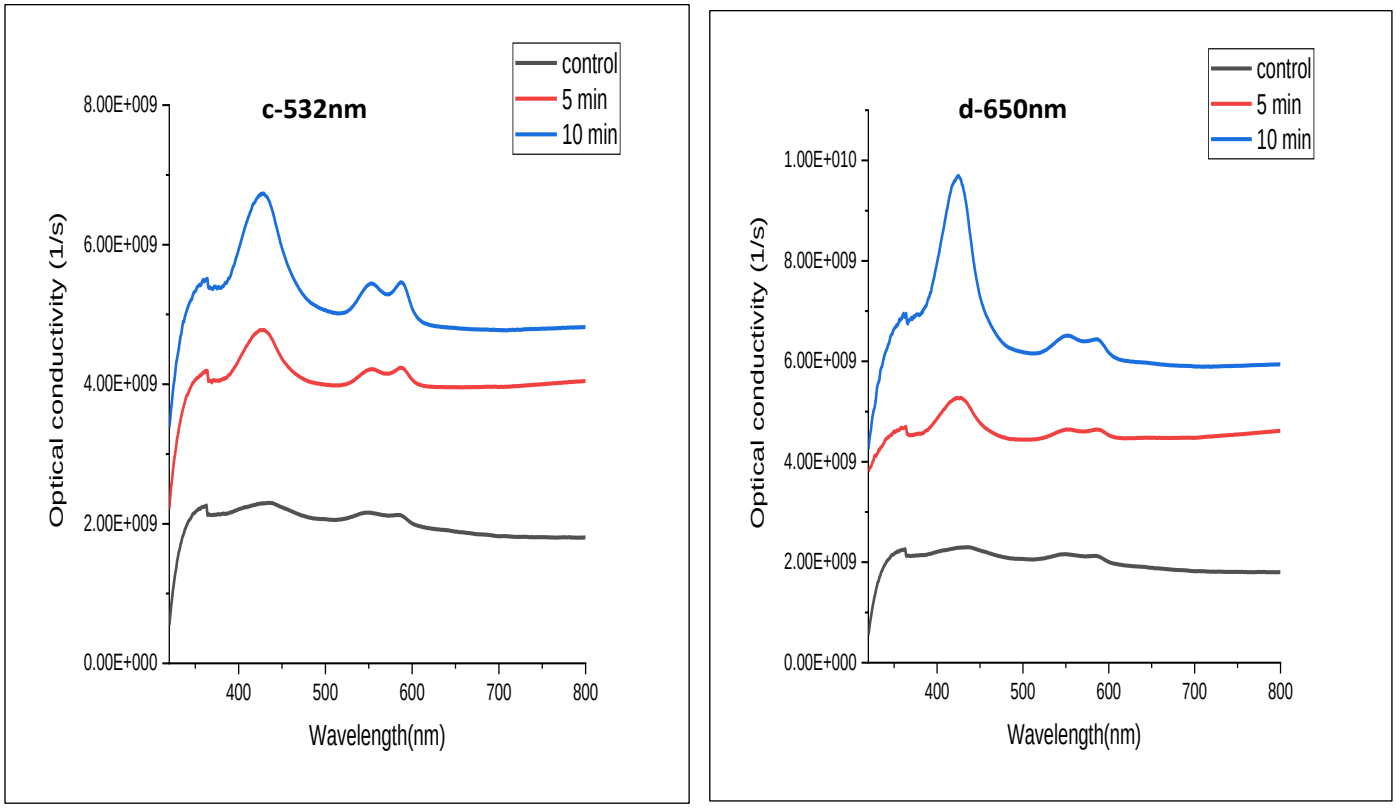


Figure (4-20-B) :Optical conductivity of blood with thalassemia before and after exposure to(c-532nm , d-650nm)

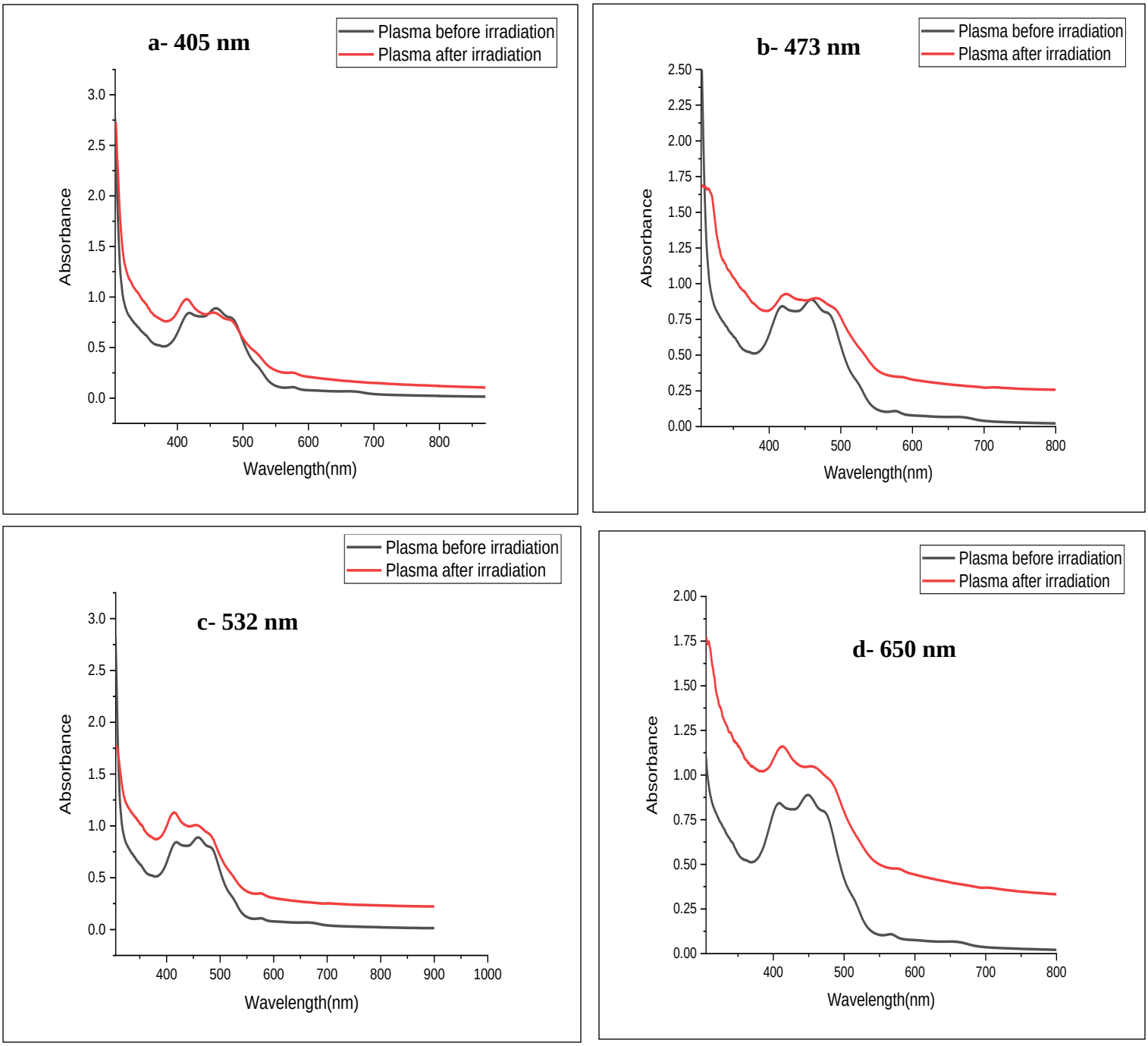
(4-8) Optical Properties of plasma for healthy blood before and after irradiation with different wavelengths:

4-8-1 Optical properties :

A. Absorbance

Figure (4-21) shows absorption spectra blood plasma after irradiation with different wavelengths (405 nm , 473 nm , 532 nm and 650 nm) , the absorption of blood plasma before irradiation has clearly peaks around (400nm) and then the absorbance gradually increases after irradiation with wavelengths (405 nm , 473 nm ,532 nm and 650 nm) but at wavelengths (405 nm and 473 nm) the absorbance is weak and increases with increasing wavelength at (532 nm and 650 nm) gradually,

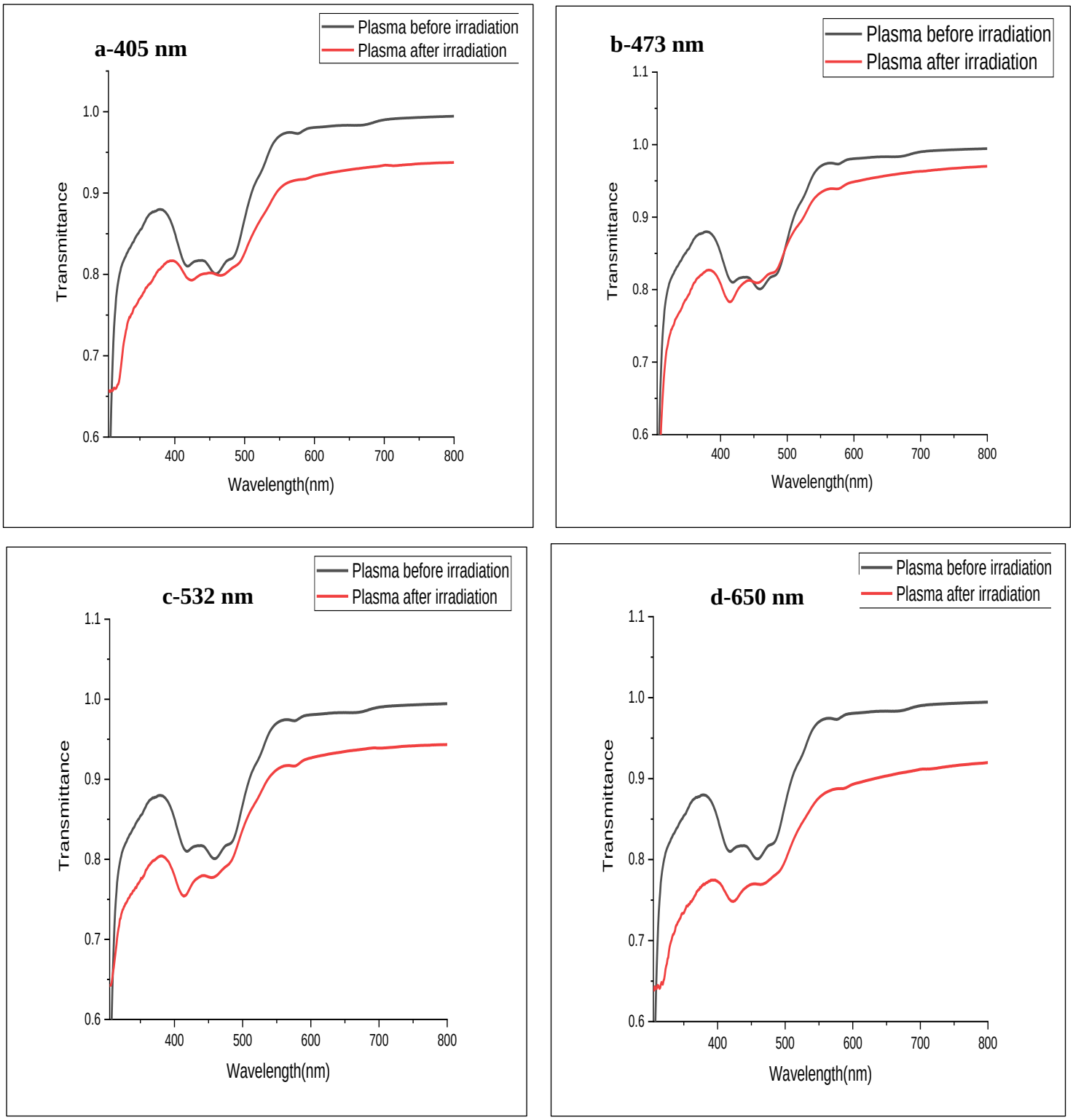
in general blood plasma contains several elements , such as water and proteins and other elements , where water is about (92 %) of its volume. Therefore the absorption in plasma is mainly through water and other elements .



Figure(4-21):Absorbance spectra of healthy plasma blood after irradiation with (a-405nm,b-473nm,c-532nm and d-650 nm)

B. Transmittance:

The relation between spectra of transmittance and wavelength of blood plasma after irradiation with different wavelength (405 nm ,473 nm , 532 nm and 650 nm) were illustrated in figure (4-22) . From figures of transmittance spectra , the transmittance spectra of blood plasma after irradiation with (405 nm and 473 nm) decreased but close to spectrum of blood plasma before irradiation because the concept of transmission is related to absorption concept . In general , transmission refer to physical process to passage of a portion of the incident light at a specific wavelength through the sample . Usually , the light loses part of it in the sample because of its absorption in the sample and gradually weakens, and the part that was not absorbed comes out of sample . The transmittance spectra of blood plasma after irradiation with wavelength (532nm and 650 nm) clearly decreases from the transmittance spectrum of blood plasma before irradiation. The transmittance of blood plasma after irradiation with (532 nm and 650 nm) lower than transmittance of blood plasma after irradiation with (405 nm and 473nm) because of weak absorption of blood plasma to the wavelength (405 nm and 473nm).

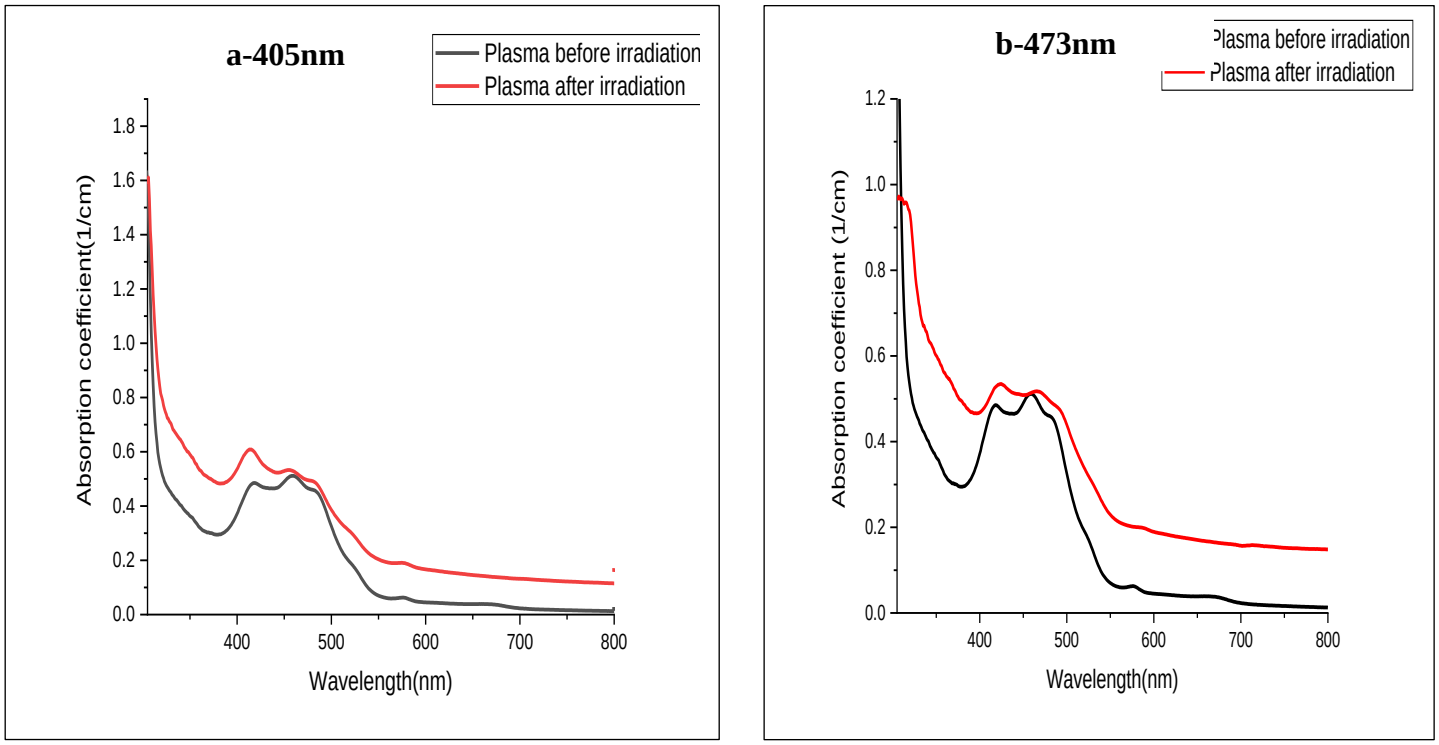


Figure(4-22):Transmittance spectra after irradiation with(a-405nm,b-473nm,c-532nm and d-650 nm)

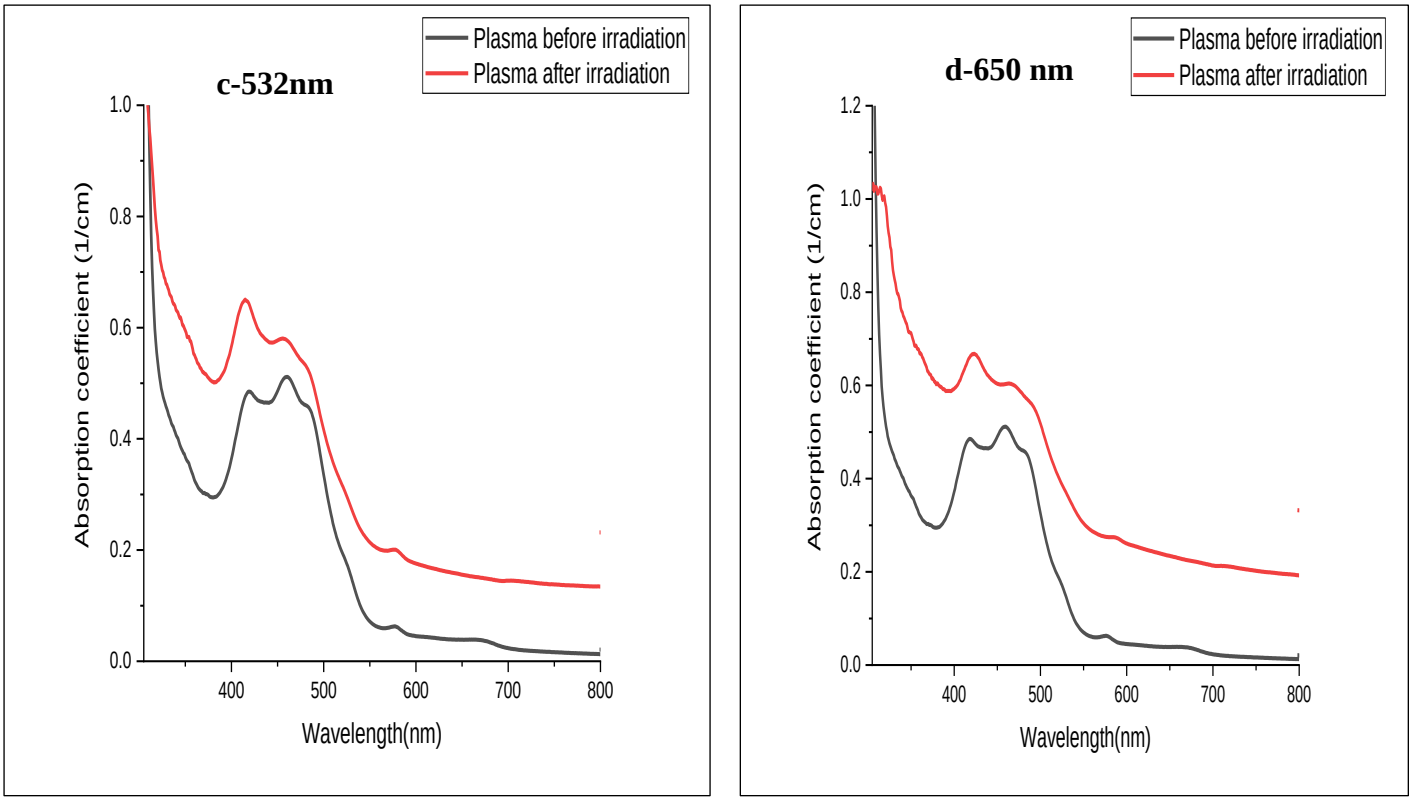
4-8-2 Optical constants :

A. Absorption coefficient:

The variation between absorption coefficient spectra and wavelength of blood plasma after irradiation with (405 nm,473nm ,532nm and 650nm) illustrate in figure (4-23-A,B) . The absorption coefficient spectra of the blood plasma sample with thickness of tube (1cm), after irradiation with deferent wavelengths increases gradually with wavelength increasing . Generally , a material that has low absorption coefficient, and if the material is thin enough , light is only poorly absorbed, and it will appear transparent to that wavelength , the absorption coefficient depends on the material and also on the wavelength of light which is being absorbed, the lower value of absorption coefficient for blood plasma sample before irradiation mean the blood plasma sample is poorly absorber , the magnitude of absorption coefficient increases after irradiation at wavelengths (405nm,473nm,532nm and 650nm).



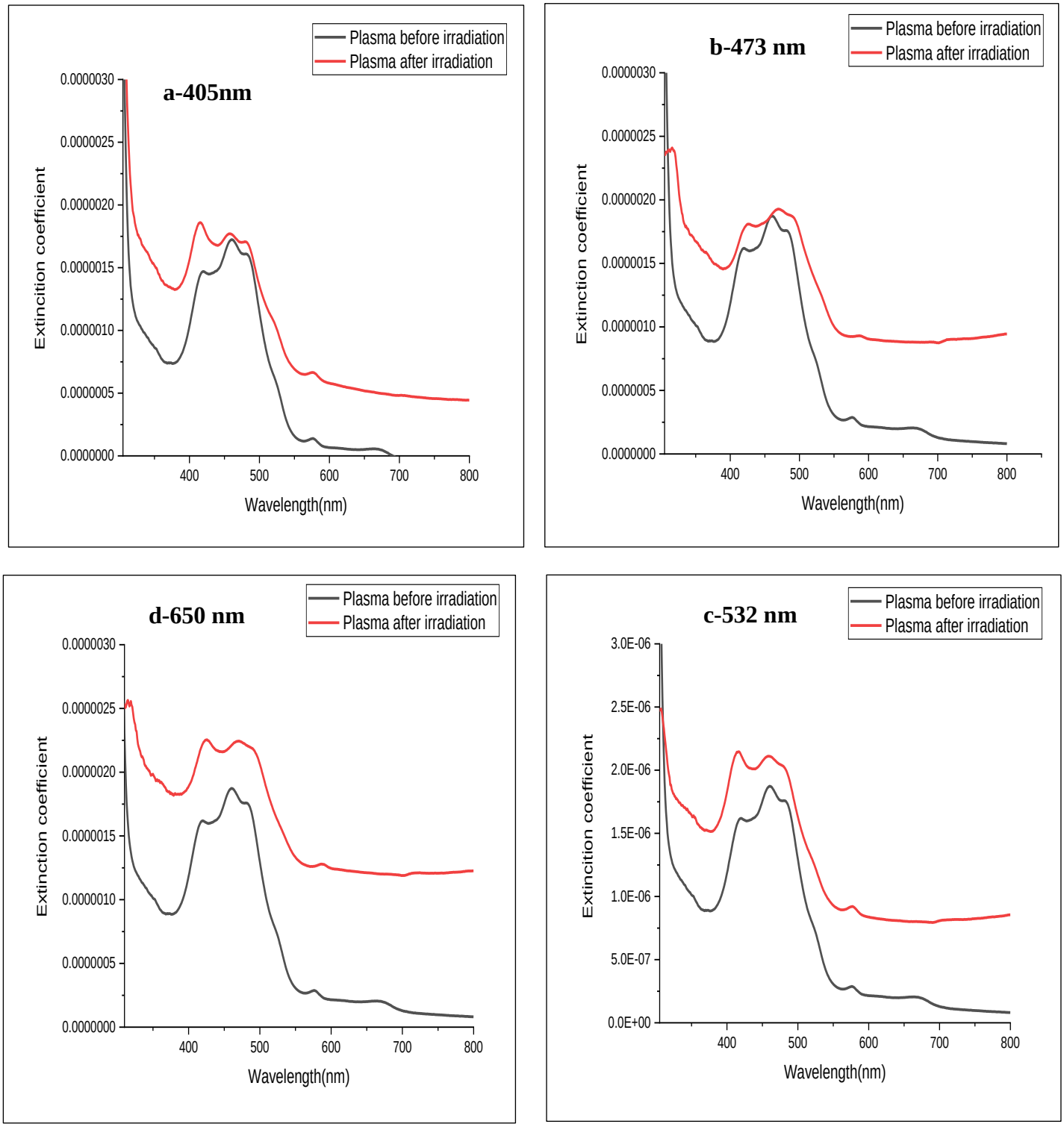
Figure(4-23-A):Absorption coefficient spectra after irradiation with(a-405nm ,b-473nm)



Figure(4-23-B):Absorption coefficient spectra after irradiation with(c-532nm , d-650nm)

B. Extinction coefficient :

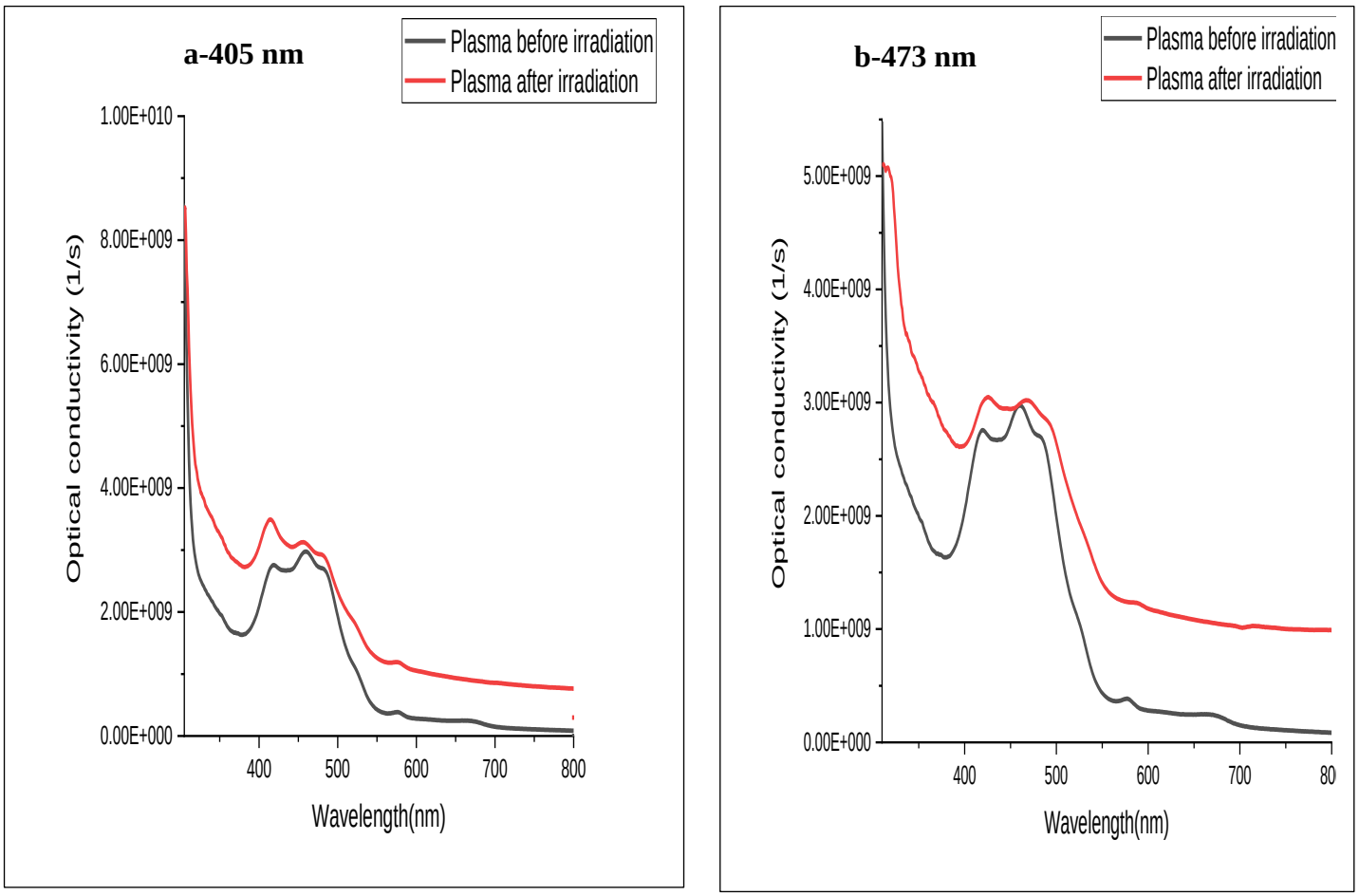
Figure (4-24) show the spectra of extinction coefficient for blood plasma before and after irradiation with different wavelengths (405nm,473nm,532 nm and 650nm). The extinction coefficient represent the amount of absorbed power when the electromagnetic radiation incident on samples , the amount of extinction coefficient depend on wavelength of incidence light and absorption coefficient of samples . The magnitude of extinction coefficient for blood plasma samples before and after irradiation with laser wavelength (405nm,473nm,532 nm,650nm) is increased gradually in the range of wavelength (300 -800) nm .



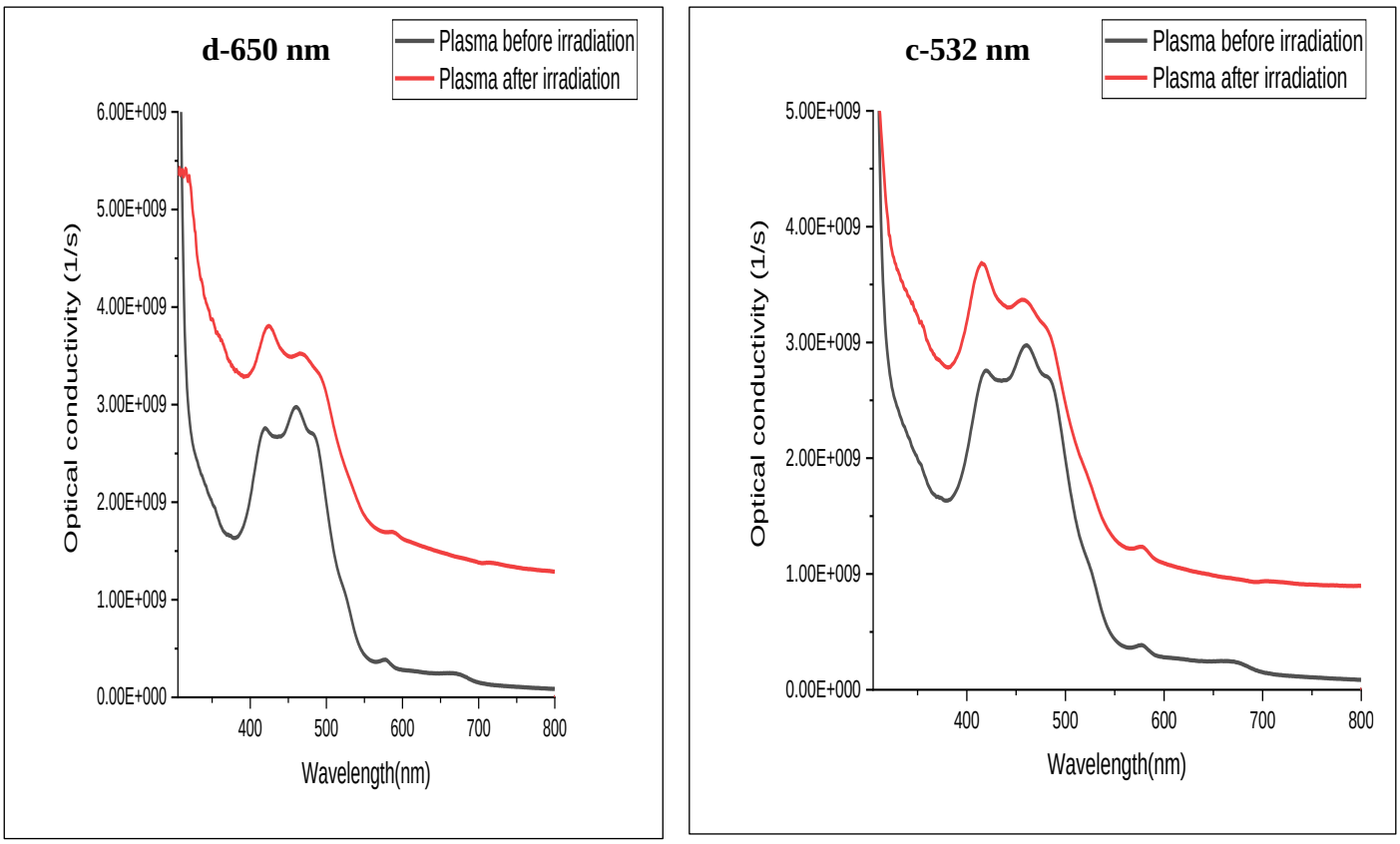
Figure(4-24):Extinction coefficient spectra after irradiation with (a-405nm,b-473nm, c-532nm and d-650nm)

C. Optical conductivity :

The optical conductivity for blood plasma samples before and after irradiation with different wavelengths (405nm,473nm,532mn,650 nm) illustrate in figure (4-25-A,B) . The magnitude of optical conductivity decreases for samples of blood plasma before irradiation with different wavelengths of laser beam and then changing with wavelength in case of laser irradiation and increasing for blood plasma samples with variable value .



Figure(4-25-A):Optical conductivity spectra after irradiation with(a-405nm ,b-473nm)

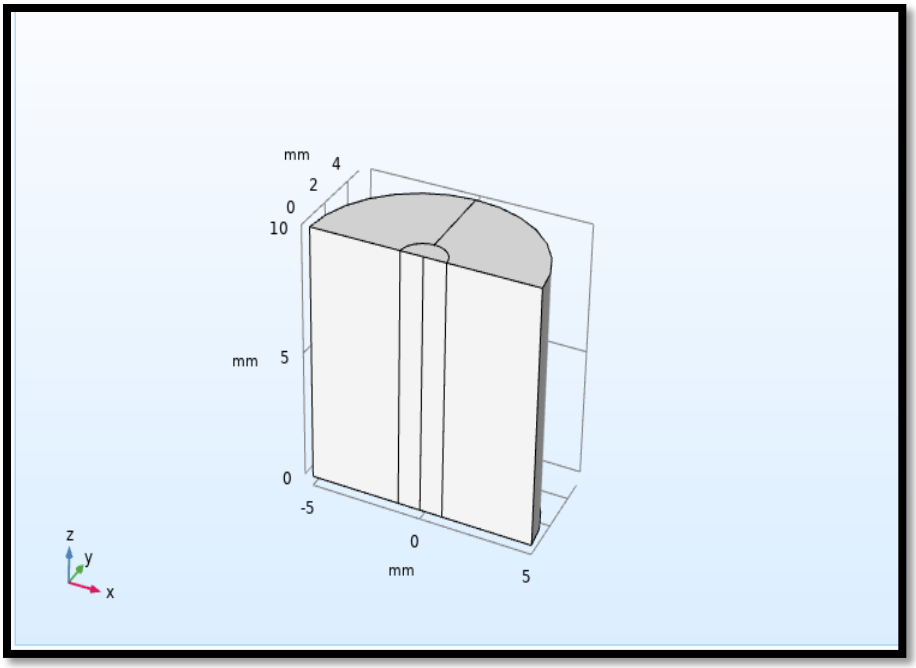


Figure(4-25-B):Optical conductivity spectra after irradiation with(a-405nm ,b-473nm, c-532nm and d-650 nm)

Part Two :Simulation Part

(4-9) Program simulation (sample description) :

According to the simulation results , the sample was imposed as a cylinder as shown in figure (4-26) , and this cylinder represents the vessel containing the blood. This cylinder contains a liquid and this liquid is a fixed and immobile , as it represents blood , it has given blood specifications in terms of thermal conductivity , specific heat in addition to blood temperature. It was considered that all surfaces of the cylinder are thermally insulated with the cylinder being cut longitudinally for the purpose of showing the thermal effects of the laser beam on the sample . The sample was exposed to a laser beam at wavelengths in the visible rang , with a power of 20 mW , and with a different exposure time (5 min and 10 min).

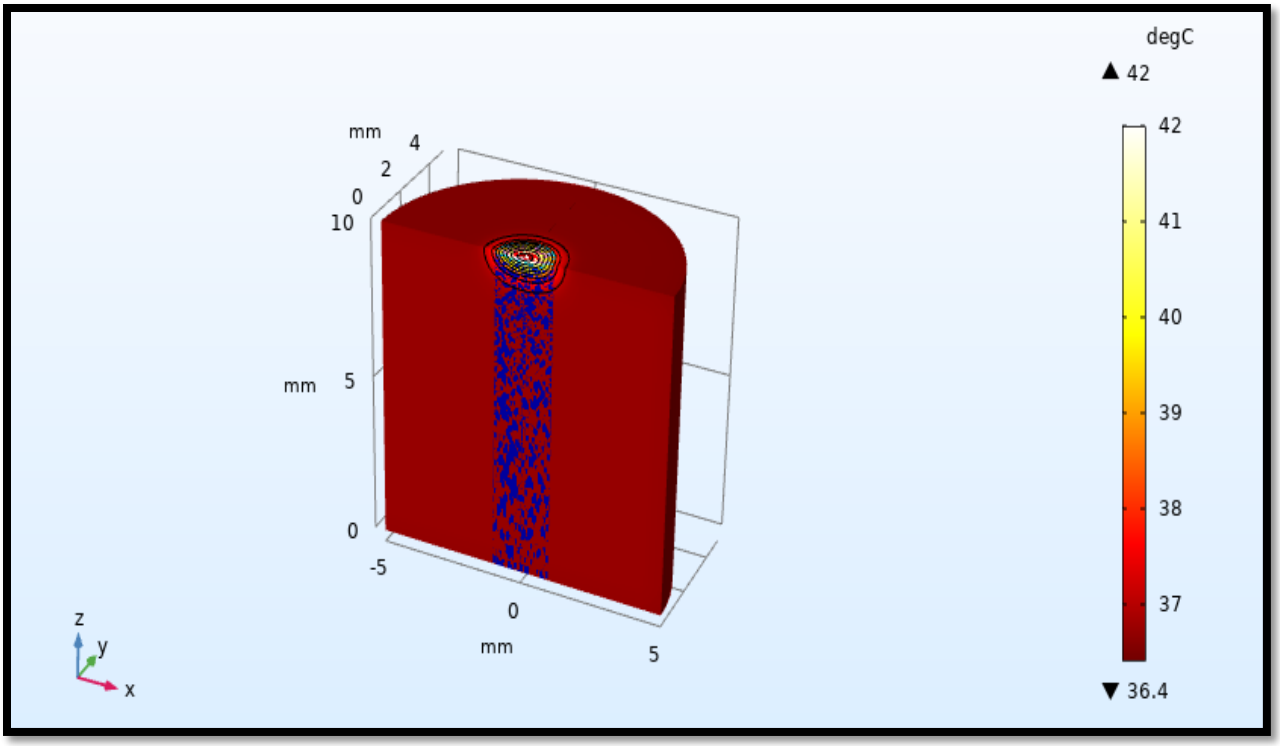


Figure(4-26): Sample of study

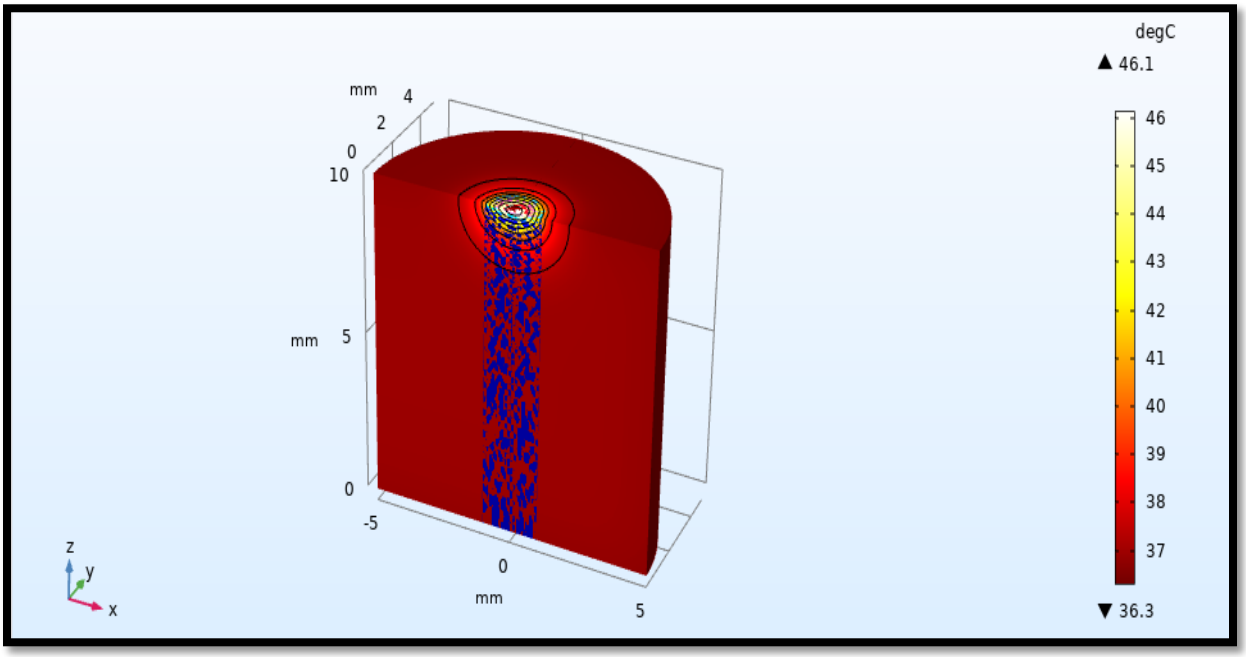
4-9-1 The effect of temperature :

During the irradiation process with CW laser that exposed on the sample tube filled with blood at exposure time (5 min,10 min) and output power (20 mW) , according to the simulation , an increase in temperature was observed for the blood sample at exposure time (5 min), the increase of temperature was gradual from 36C^{o} to 42C^{o} and reached to the part of surrounding gradually . By increasing the irradiation time to 10 min , the temperature increased to 46.1C^{o}.

The higher temperature in the center of the sample and decreasing down to the tube walls , the thermal effect of the CW laser on the blood sample is confined to a specific area in the sample and spreads gradually and does not reach a high depth through the sample , as shown in figure (4-27) and (4-28).



Figure(4-27): heat transformation through the sample at (5 min)

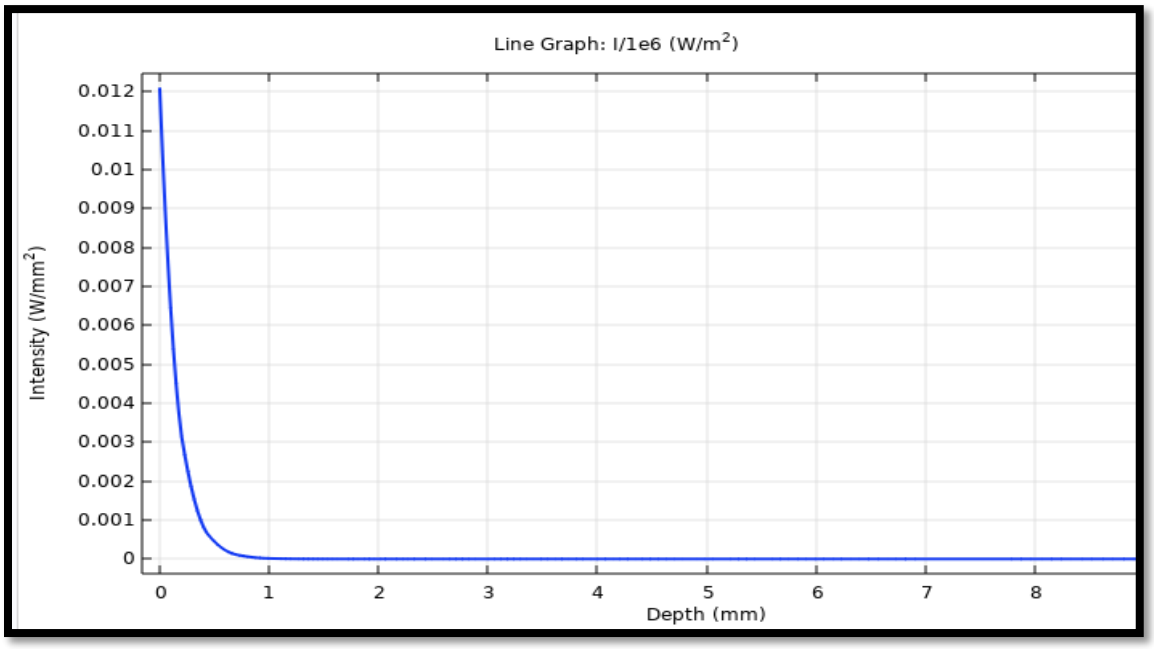


Figure(4-28): heat transformation through the sample at (10 min)

4-9-2 The relation between penetration depth and intensity :

According to the figure (4-29) that shows the relation between the intensity of the laser beam directed at sample and the depth of penetration .

The relation between intensity of laser radiation and penetration depth according to the simulation results is exponential and with increasing intensity the penetration depth increases at intensity (0.012 W/mm^2) with exposure time 5 min and this depth increases when increasing the exposure time at the intensity (0.012 W/mm^2) with exposure time 10 min , and from this it becomes clear that the increases the penetration depth of radiation falling on the sample .

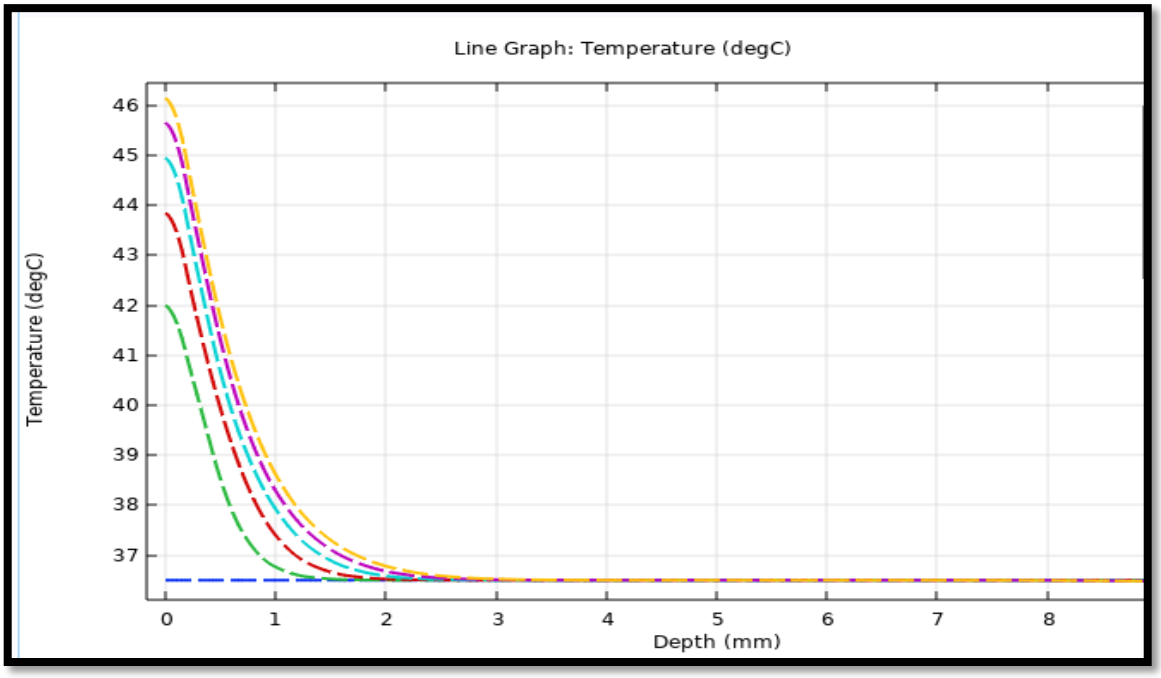


Figure(4-29): The relation between penetration depth and intensity

4-9-3 The relation between penetration depth and temperature :

Figures (4-30 , 4-31 and 4-32) shows the relation between depth of penetration and temperature, as the temperature increases the depth of penetration increases , and this explains the process of diffusion occurring in the sample . The temperature

inside the sample increases gradually from 36 C to 46 C when the exposure time increased and as a result , the penetration depth increased .



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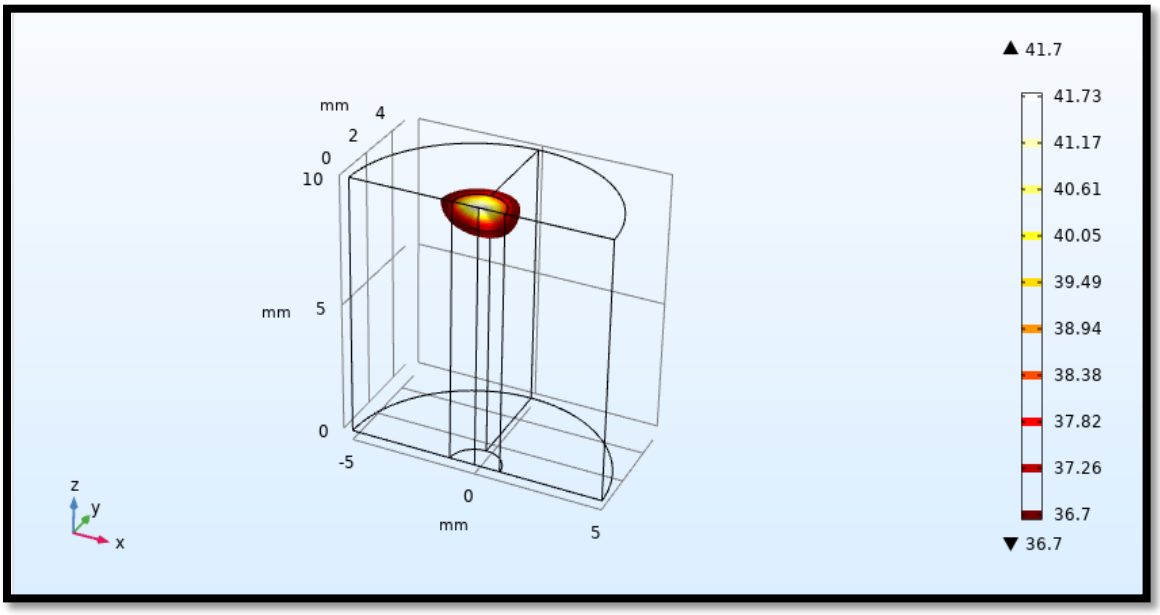
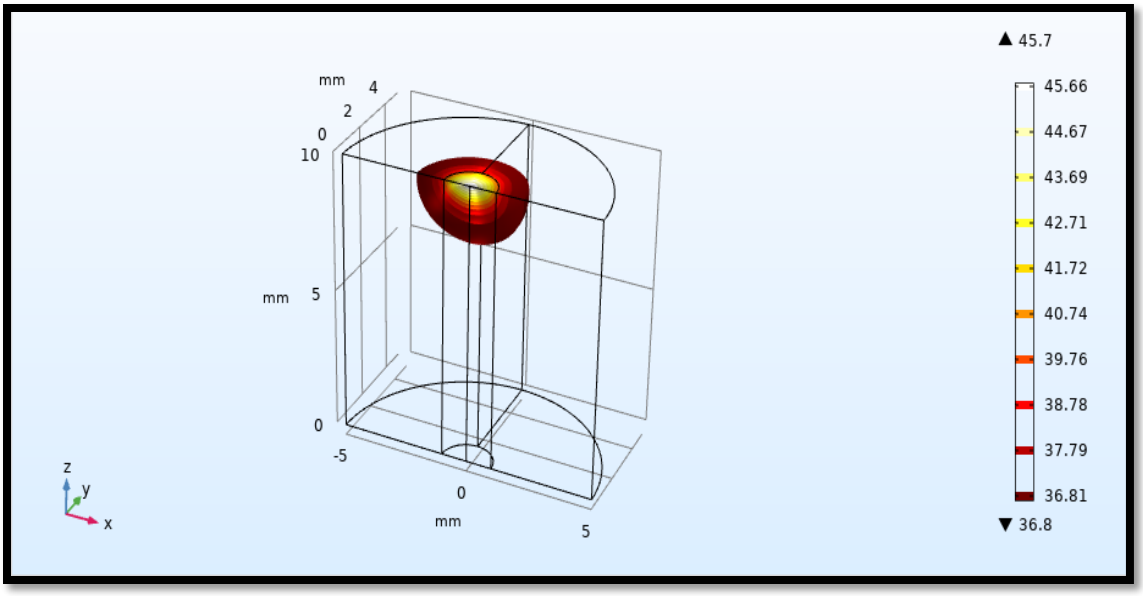
Figure(4-30): The relation between penetration depth and temperature



Figure(4-31): The relation between penetration depth and temperature at exposure time 5min



Figure(4-32): The relation between penetration depth and temperature at exposure time 10min

(5-1) Conclusions:

Through the results that were presented and discussed , a number of the following conclusions were reached :

Through the optical properties optical properties of blood samples , it is possible to know healthy blood from infected blood ,and this is a new method of blood examination in a physical way that easier and faster than the traditional laboratory methods . The absorbance process of healthy blood sample before irradiation with different wavelengths is higher than absorption in anemic blood and blood with thalassemia samples .

The values of optical constants (absorption coefficient , extinction coefficient , optical conductivity) are higher than its values in anemic blood samples and samples of blood with thalassemia , respectively .The absorbance of healthy blood samples increased after irradiation with different wavelength (405nm,473nm,532nm and 650 nm) at exposure time (5min and 10 min) and then (transmittance ,reflectance) decreased respectively for all samples .The samples of anemic blood has absorbance after irradiation with different wavelengths (405nm,473nm,532nm and 650nm) at different exposure time (5min and 10 min) , higher than absorbance of anemic blood samples before irradiation . The temperature inside the sample increased with increasing of exposure time to the laser irradiation. The penetration depth of laser radiation increased when the exposure time was increased .

(5-2) Future works :

1- Using different laser wavelengths, energy and different times on blood samples outside the body and performing other tests.

2- Measuring the effect of laser radiation on the concentration of oxidizing agents and oxidation products on the one hand and the efficiency of enzymatic and non-enzymatic antioxidants.

3- Exposing blood samples to low-power laser beams and isolating nucleic acids for the purpose of knowing the effect of laser beams on the composition of nucleic acids (nitrogenous bases) and the enzymes responsible for repairing nucleic acids (DNA, RNA).

4- Determination of the amount of oxygenated hemoglobin (oxy-hemoglobin) and deoxy-hemoglobin (deoxy-hemoglobin) after exposing blood samples to high-energy and low-energy laser beams.

5 . Knowing the effect of the laser beam on the effectiveness of blood clotting factors by measuring the prothrombin time (PT) and activated prothrombin time (APPT) to evaluate the special effectiveness of the laser beam on accelerating or suppressing the effectiveness of blood clotting factors.

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