Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/12060
DOI URL: http://dx.doi.org/10.21474/IJAR01/12060

RESEARCH ARTICLE

EFFECTS OF 532 NM AND 671 NM LASERS IRRADIATION ON ABSORPTION COEFFICIENTS OF NORMAL AND ANEMIC HUMAN BLOOD SAMPLES

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Manuscript Info

Manuscript History
Received: 15 September 2020
Final Accepted: 18 October 2020
Published: November 2020

Key words:-
Laser Irradiation, Optical Properties, Absorption Coefficient, Normal and Anemic Human Blood Samples

Abstract

The effects of laser irradiation on the absorption coefficients of the normal and anemic human blood samples were investigated. Two continuous wave (CW) diode - pumped solid - state lasers (DPSSL's) of different wavelengths, 532 nm and 671 nm, were used.The output power of these lasers can be adjusted over the range 0 - 100 mW. In the present study, the output power of both lasers was fixed at 20 mW.The blood samples were irradiated at different irradiation times, 5, 15, and 30 min.The absorption coefficients of the normal and anemic human blood samples were determined from the measurements of the absorbance spectra of the unirradiated and irradiated samples. The absorbance spectra were measured using UV - Visible double - beam spectrophotometer operating over the wavelength range 190-1100 nm. Significant changes in the absorption coefficients of the irradiated blood samples were observed compared to the unirradiated blood samples.The results obtained in the present investigation showed that there are significant effects of laser irradiation on the optical properties of the human blood samples.These effects can result in noticeable changes in their absorption coefficients. The results suggested that the technique used in the present investigation has great potential to be a useful tool for the clinical diagnostics and the medical applications.

Introduction:-

Laser irradiation of blood and biological tissues has been increasingly used in many biological and medical applications [1 - 7]. For these applications, the knowledge of the optical properties of tissues is of great importance for the interpretation and quantification of the diagnostic data for the prediction of light distribution and absorbed energy for therapeutic use. Exposure of blood and biological tissues to the laser radiation can produce significant changes in the optical properties and the structures of these biological materials [3, 8, 9].The effects of laser irradiation on the biological materials depend on the experimental conditions such as, the type of the biological material irradiated, the wavelength and the intensity of the laser radiation beam, and the irradiation time. The changes in the optical properties of the blood and the biological tissues can be determined from the measurements of the changes in optical parameters of the blood and the biological tissues such as, absorbance (A), transmittance (T), reflectance (R), refractive index (n), and absorption coefficient (α). For a better understanding of the responses of these parameters to the laser beam irradiation, further studies are needed to investigate the biological effects of interaction of laser radiation with biological materials. There are several techniques can be used for measuring the

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changes in the optical parameters of the biological materials [3, 10 - 15]. Among the various optical techniques, the UV - Visible spectroscopic technique, which is the most important and popular analytical technique for gaining detailed information about the structures, the biochemical compositions, and the optical properties of the biological material [16 - 18]. This technique has received special considerations due to its advantages such as, the simplicity, the high sensitivity, high resolution, and the rapid measurements, as compared to other techniques. Due to its non-invasive nature, the UV - Visible spectroscopic technique has found increasing applications in the various biomedical fields [19 - 24].

In the present work, the effects of 532 nm and 671 nm laser irradiation on the absorption coefficients of the normal and the anemic human blood samples were studied and the values of these absorption coefficients were determined.

Materials and Method:-

Blood Samples Preparation

Human blood samples of 3 ml were collected from 10 healthy participants and 10 participants with anemia disease. These blood samples were collected in glass tubes containing Ethylene Diamine Tetraacetic Acid (EDTA) as an anticoagulant. Each sample of the normal blood and anemic blood was divided into three samples of equal volumes, one of these samples was used as a control sample (unirradiated sample), while the other two samples were irradiated with the 532 nm or 671 nm lasers. The blood was diluted with NaCl solution (normal saline solution), 1 ml of NaCl solution for each 20 µl of blood.

Laser Irradiation and Measurements

In the present study, two continuous wave (CW) lasers diode - pumped solid - state lasers (DPSSL's) with different wavelengths, 532 nm (green laser beam) and 671 nm (red laser beam), were used. The output power of each laser can be varied over the range 0 - 100 mW. In the present study, the output powers of the two lasers were fixed at 20 mW. Each laser was placed vertically at a distance 6 cm from the blood surface, and the laser beam was incident normally toward the blood sample.

The output beam of both lasers has a Gaussian single transverse mode (TEM_{00}) profile with a diameter of 4 mm. The blood was placed in a 1 cm cuvette before sample irradiation. The blood samples were irradiated with the laser beam of the wavelength 532 nm or 671 nm at different irradiation times, 5, 15, and 30 min. The delivered flounces (the exposure doses) corresponding to the irradiation times are, 47.77, 143.32, and 286.63 J / cm^2, respectively.

The absorption spectra of the unirradiated and the irradiated blood samples, for the normal blood and anemic blood, were measured and analyzed before and after irradiation by using double - beam spectrophotometer (Cecil Model CE - 7500) of the wavelength range 190 - 1100 nm.

Results and Discussion:-

Different samples of the human normal blood and anemic blood were irradiated with a laser beam of the wavelength 532 nm or 671 nm for different irradiation times, 5, 15, and 30 min. Two unirradiated samples were used as control samples for the normal blood and the anemic blood.

The absorption coefficient (α) of a blood sample can be described by the Lambert - Beer law as [26]:

$$I = I_0 e^{-\alpha L} \quad (1)$$

where I_0 is the incident light intensity, I is the transmitted light intensity, and L is the length of the blood sample. If the absorbance (A) of the blood sample is defined by: $A = I_0 / I$, then Eq. (1) can be written as follows [26, 27]:

$$A = e^{\alpha L} \quad (2)$$

or it takes the form:

$$\alpha = 2.303 \frac{A}{L} \quad (3)$$

The absorption coefficient (α) of each blood sample was calculated by using the relation (3). The value of A was determined from the spectrum of the absorbance, the absorbance (A) versus the light wavelength (λ). The absorbance spectrum was measured by using the double - beam spectrophotometer over the wavelength range 300 - 900 nm in the ultraviolet and visible regions.

Figs. (1) - (4) show the calculated absorption coefficient (α) as a function of the incident photon energy (hν) for the control (unirradiated) human blood samples, and, the normal and the anemic human blood samples irradiated with a laser beam at wavelengths 532 nm and 671 nm for different irradiation times, 5, 15, and 30 min.

Fig. 1 shows the relation between the absorption coefficient (α) of the normal human blood sample and the incident photon energy (hν), for the unirradiated (the control) blood sample and irradiated blood samples with the laser beam of the wavelength 532 nm, at different irradiation times. It is observed that all the blood samples exhibit four peaks of different heights at the incident photon energies (hν), 2.13, 2.31, 3.00, and 3.60 eV. The peaks with the highest absorption coefficients for the control blood sample and the blood samples irradiated with the laser beam at the irradiation times, 5, 15, and 30 min, are located at the incident photon energy (hν) of 3.00 eV.The highest value of absorption coefficient (α) is 5.26 cm^{-1} at the incident photon energy (hν) of 3.00 eV, for the irradiation time 30 min.

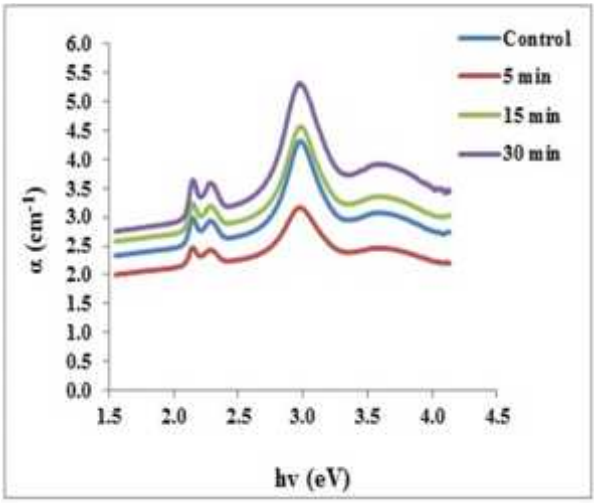

Fig.1:- Absorption coefficient (α) of the control normal blood sample and the irradiated normal blood samples with laser radiation at the wavelength 532 nm as a function of the incident photon energy (hν), for different irradiation times.

Fig. 2 shows the relation between the absorption coefficient (α) of the anemic human blood samples and the incident photon energy (hν), for the unirradiated blood sample and irradiated blood samples with the laser beam of the wavelength 532 nm, at different irradiation times.

It is clearly noticed that the highest peaks are located at the incident photon energy (hν) of 3.00 eV. The highest value of absorption coefficient (α) is 4.52 cm^{-1} at the incident photon energy (hν) of 3.00 eV, for the irradiation time 30 min.When compare the values of the absorption coefficient (α) of the irradiated anemic human blood samples with that of the irradiated normal blood samples, we find that the values of the absorption coefficient (α) of the irradiated anemic human blood samples are lower than the values of the irradiated normal blood samples.The highest value of absorption coefficient (α) is reduced from 5.26 cm^{-1}, for the normal blood sample, to 4.52 cm^{-1}, for the anemic blood sample.

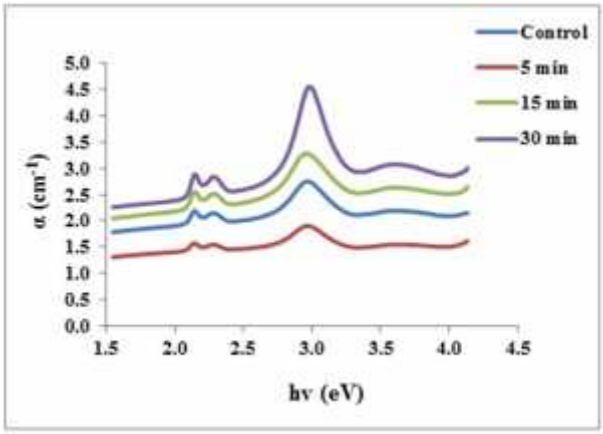

Fig. 2:- Absorption coefficient (α) of the control anemic blood sample and the irradiated anemic blood samples with laser radiation at the wavelength 532 nm as a function of the incident photon energy (hv), for different irradiation times.

Fig. 3 shows the relation between the absorption coefficient (α) of the normal human blood samples and the incident photon energy (hv) for the unirradiated sample and irradiated samples with the laser beam of the wavelength 671 nm, at different irradiation times.The highest value of absorption coefficient (α) is ≈ 4.29 cm^{-1} at the incident photon energy (hv) 3.00 eV, for the irradiation time 30 min.

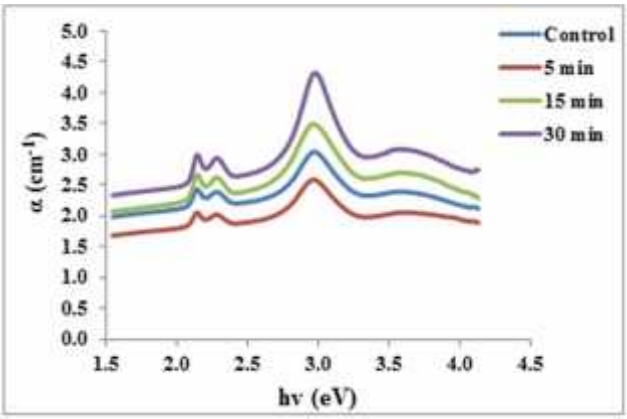

Fig. 3:- Absorption coefficient (α) of the control normal blood sample and the irradiated normal blood samples with laser radiation at the wavelength 671 nm as a function of the incident photon energy (hv), for different irradiation times.

Fig. 4 shows the relation between the absorption coefficient (α) of the anemic human blood samples and the incident photon energy (hv) for the unirradiated sample and irradiated samples with the laser beam of the wavelength 671 nm, at different irradiation times. The highest value of absorption coefficient (α) is 3.25 cm^{-1} at the incident photon energy (hv) 3.00 eV, for the irradiation time 30 min. It is found that the values of the absorption coefficient (α) of the irradiated anemic blood samples are lower than the values of the irradiated normal blood samples.The highest value of absorption coefficient (α) is reduced from 4.29 cm^{-1}, for the normal blood sample, to 3.25 cm^{-1}, for the anemic blood sample.

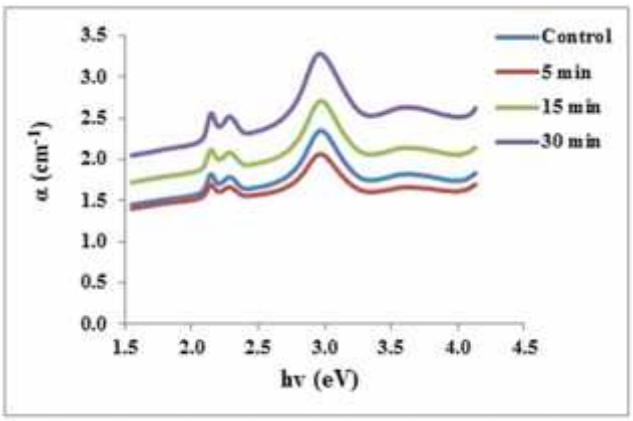

Fig. 4:- Absorption coefficient (α) of the control anemic blood sample and the irradiated anemic blood samples with laser radiation at the wavelength 671 nm as a function of the incident photon energy (hv), for different irradiation times.

It is obvious from the obtained results that the absorption coefficient values of the blood samples are significantly affected by the presence of the laser irradiation, and these values increased as the irradiation time increased. The absorption coefficient values of the normal blood samples and the anemic blood samples before and after irradiation with the laser beam of the wavelengths 532 nm and 671 nm, for different irradiation times are summarized in Tables (1) and (2), respectively.The results show that both the normal and the anemic human blood samples irradiated with the laser beam of the wavelength 671 nm have lower values of absorption coefficient (α) than the values of the blood samples irradiated with the laser beam of the wavelength 532 nm.

Table 1:- The calculated absorption coefficient values of the normal blood samples and the anemic blood samples before and after irradiation with the laser radiation beam of the wavelength 532 nm, for different irradiation times.

Photon Energy hv (eV)	Normal blood sample α (cm^{-1})				Anemic blood sample α (cm^{-1})			
	Control	5 min	15 min	30 min	Control	5 min	15 min	30 min
2.13	2.8952	2.4034	3.1507	3.5400	2.1572	1.5572	2.5211	2.8248
2.31	2.9216	2.4372	3.1724	3.5421	2.1229	1.5297	2.4901	2.8057
3.00	4.2768	3.1996	4.5501	5.2624	2.7219	1.8875	3.2368	4.5246
3.60	3.0790	2.4641	3.3687	3.9096	2.1918	1.5479	2.6366	3.0787

Table 2:- The calculated absorption coefficient values of the normal blood samples and the anemic blood samples before and after irradiation with the laser radiation beam of the wavelength 671 nm, for different irradiation times.

Photon Energy hv (eV)	Normal blood sample α (cm^{-1})				Anemic blood sample α (cm^{-1})			
	Control	5 min	15 min	30 min	Control	5 min	15 min	30 min
2.13	2.3796	2.0140	2.5861	2.8885	1.7840	1.6713	2.0787	2.4992
2.31	2.3616	1.9959	2.5911	2.9015	1.7660	1.6460	2.0625	2.4924
3.00	3.0152	2.5580	3.4553	4.2875	2.3280	2.0442	2.6887	3.2532
3.60	2.3915	2.0531	2.6989	3.0736	1.8230	1.6620	2.1428	2.6381

Conclusions:-

The effects of the laser irradiation on the absorption coefficients of the normal and the anemic blood samples were studied and the absorption coefficient values of these samples were determined. Two continuous wave (CW) diode - pumped solid - state lasers (DPSSL's) of different wavelengths, 532 nm and 671 nm, were used for the irradiation blood samples. It is observed that the exposure of blood samples to the laser radiation causes clearly defined changes in the absorption coefficients of these samples. The values of the absorption coefficients of both the

normal and the anemic blood samples increase with increasing the irradiation time. It is also observed that the values of the absorption coefficient (α) of the anemic blood samples are lower than the values of the normal blood samples. It is found that these values depend on the wavelength of the laser beam used for the irradiation of the blood sample.The values of the absorption coefficient of the blood samples irradiated by the laser beam of the wavelength 671 nm are lower than the values of the blood samples irradiated by the laser beam of the wavelength 532 nm.
Results indicated the suitability of the spectroscopic technique, used in the present study, for the clinical diagnostics and the biomedical applications.

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