American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)
ISSN (Print) 2313-4410, ISSN (Online) 2313-4402
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http://asrjetsjournal.org/

Evaluation of a Constructed Optical Coherence Tomography System

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Abstract

The objective of this work is to design and construct an optical coherence tomography (OCT) system, beside the comparison of the efficiency of this system with other tomography systems, like Photoacoustic system, to evaluate its operation. Michelson interferometer was designed; which represent the heart of the system. Two types of laser sources were used; they were He-Ne laser with wavelength of 632.8 nm and semiconductor laser with wavelengths of (700) nm. Performance of the constructed system was completed by receiving the interference fringes by an optical detector, which was connected to the display unit. Digital oscilloscope, with Fourier transformation, was used to display the signal information in frequency domain. Also CCD camera was used to give two & three dimensional images for the studied samples. The constructed system can be used for many purposes, for examples: measurement of the thickness and determination of the optical properties for different samples. The samples studied by the constructed OCT system were: glass slides, polymer\ pyrex\ carbon coating, layers of onion. To prove the good performance of the constructed OCT system the results were compared with other results gained by a Photoacoustic system for the polymer sample. The comparison proved that the constructed OCT system is operated efficiently and correctly.

Keywords: Tomography Imaging; FT; Optical properties (:).

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1. Introduction

Nowadays, a broad variety of imaging techniques are becoming available [1]. Tomography imaging techniques, such as: X-ray computed tomography, magnetic resonance imaging, and ultrasound imaging have found widespread applications in medicine. Each of these techniques measure a different physical property and has a resolution and penetration range that prove advantageous for specific applications [2].

Optical coherence tomography (OCT) is a non-invasive imaging test [3,4,5]. It has the ability to peer inside the body, tissue absorption and scattering coefficients are derived from the characteristics of scattered light transmitted and / or re-emitted by the body. Three basic optical tomography approaches have been developed [6].

Diffraction tomography, (ii) Diffusing photon tomography [7]. (iii) Optical coherence tomography (OCT) [8].

The most straight forward optical technique is by diffraction tomography.

Diffraction tomography is the part of the general problem of inverse scattering. A basic mathematical theorem used to perform the reconstruction of the object structure is the Fourier diffraction [9].

In this work, the approach of optical coherence tomography (OCT) was chosen.

Optical Coherence Tomography (OCT) is an imaging technology measuring the backscattering properties of tissue, or material. Recently, extensions of OCT technology, including; Doppler flow and polarization sensitive image, have been developed that permit spatially resolved imaging of velocity or birefringence [10].

OCT has potential to go inside the tissue or material and give us the information from the reflected light. OCT performs imaging by measuring the echo time delay and intensity of backscattered light from internal microstructure in the tissue or material [11].

OCT combines the principle of ultrasound with the imaging performance of a microscope, where as ultrasound produced images from backscattered sound, OCT uses light. Cross-sectional images [12,13] are generated by measuring the echo time delay and intensity of light that is reflected or backscattered from internal structure in tissue, or material. Because the velocity of light is extremely high, the echo time delay can not be measured directly. Instead, it is necessary to use correlation or interferometery techniques [14].

In an OCT system the spectrum of the source is very important as it determines the maximum resolution of the image.

1.1 The general requirements of sources of OCT imaging are: [15]

1- Emission in near IR 2- Short coherence length 3- High irradiance

1.2 Applications of OCT

Since OCT has a much higher resolution[16,17] compared to other imaging modalities, OCT has emerged as a promising medical diagnostic imaging technology for non invasive in situ cross-sectional imaging of biological tissues and materials [18, 19]. it has significant potential in medical diagnosis [20]. The ability to image internal structures without the need for mechanical probing makes this technique very powerful for medical applications [21]. Its applications in ophthalmology, dermatology, endoscope, cardiology, vascular morphology, gastroterology, dentistry, and embryology have been demonstrated by several groups [22].

2. Material and methods

OCT system constructed for the aim of this work consists of five parts: two laser sources (He-Ne of 632.8 nm, 4 mW, class III, CW diode lasers 700 nm, ≤ 4.25 mW, class III. Constructed Michelson interferometer, detector (optical detector, photomultiplier detector), digital oscilloscope (150 MHz), computer, printer (RS-232 C thermal printer) and CCD (LBA-100A) camera.

Different samples were used, to prove that the constructed system can be used for different purposes successfully. The used samples were: polymer (polycorbolen), carbon coating (SPI 5006 supplies made in U.S.A, conductive carbon point), glass (microscope slices, with thickness of 1mm and 1.2mm), onion, Pyrex (slide with thickness of 0.1 mm).

2.1 OCT experiment procedure was done in steps as fallows

1-Michelson interferometer was constructed.

2- Interference pattern of the object was obtained.

3- Photodetector was used to convert an optical signal into an electrical signal.

4- The detector output was displayed as voltage value when it is connected to a digital oscilloscope.

5- Computer or printer was connected serially with digital oscilloscope to display, or print, the detector output signal.

6- Two and three dimensional images of the object were obtained; when the interference fringes were receive by CCD camera.

7- The constructed OCT system was used with different samples for multi purposes. Information like depth, optical properties were determined from the digital oscilloscope signal.

To describe the operation of the optical coherence tomography system, the signal should be followed in each stage. First, laser light incident on the beam splitter, which reflects half of the incident light to the reference mirror which was fixed, and the other half of the incident light was transmitted to the object (the sample) through the concave lens in order to concentrate the light when it passed or reflected from the object. Figure (1) shows the block diagram of the constructed system.

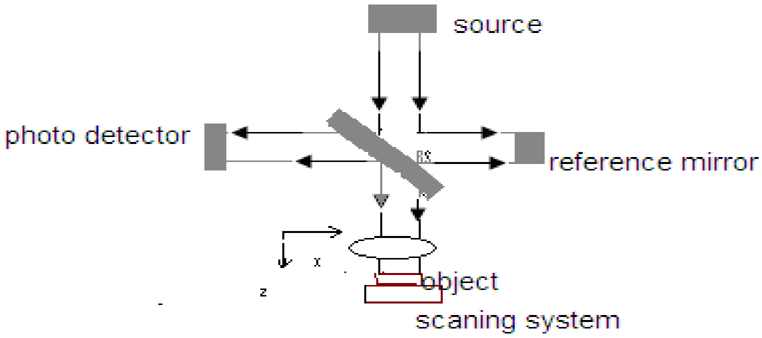


Figure 1: block diagram of the constructed (OCT) system

Then the two beams were reflected or backscattered again to the beam splitter, and interference fringes were observed after some adjustment done by screws on the fixed mirror. This step was done for all the samples and to scan the sample depth, a micrometer screw was used. The performed pattern was received by the detector to convert it into voltage, which was displayed on the digital oscilloscope. Many steps were done to determine the optical properties for all studied samples. The intensity of that signal was represented (plotted) against scanning distance; the obtained graph was used to determine penetration depth and absorption coefficient. From absorption coefficient, all other optical properties can be calculated. Figures (2) and (3) show the constructed optical coherence tomography system with different detection devices.

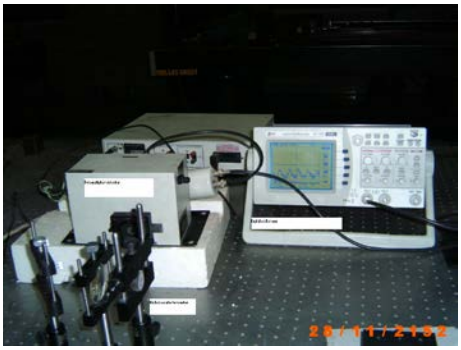


Figure 2:

The constructed OCT system

using photomultiplier detector

Figure 3:

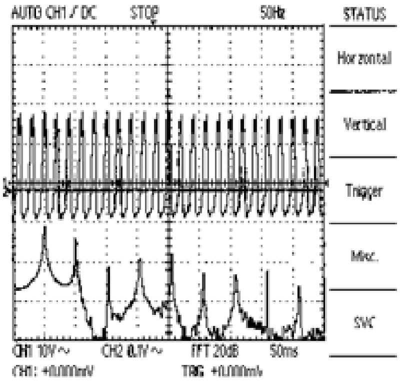
The constructed OCT system

using CCD camera to determine 2-D & 3D images

At the end, the constructed OCT system results were compared with Photoacoustic system to evaluate its operation.

3. Results and discussions

The experimental results were represented in tables and figures. Figures (4) to (9) show the experimental results recorded by digital oscilloscope.



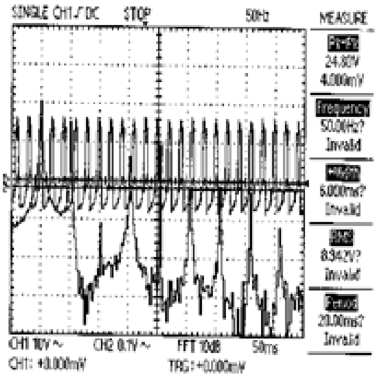
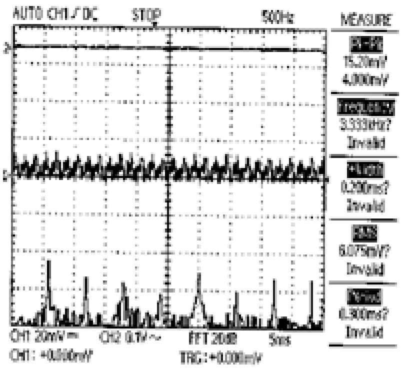


Figure 4: the signal recorded by

digital oscilloscope for glass 1.0mm

Figure 5: the signal recorded by

digital oscilloscope for glass 1.2mm



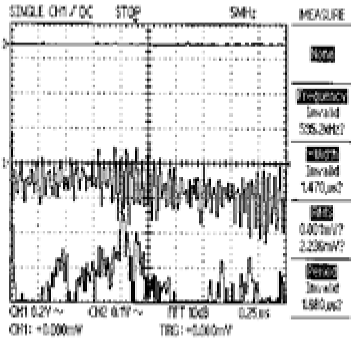
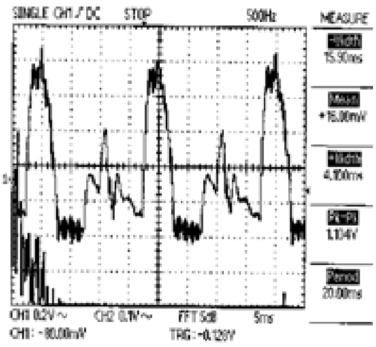


Figure 6: the signal recorded by digital

oscilloscope for pyrex 0.1mm

Figure 7: the signal recorded by digital

oscilloscope for polymer



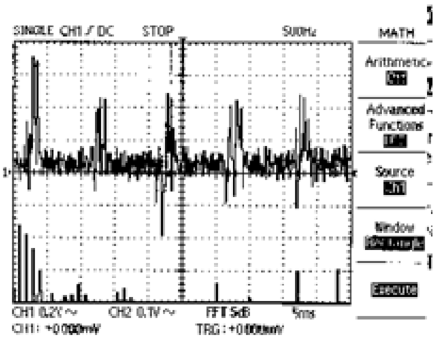


Figure 8: the signal recorded by digital

oscilloscope for carbon coating

Figure 9: the signal recorded by digital

oscilloscope for onion

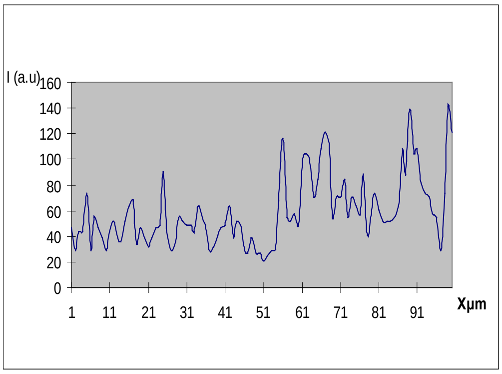
From the signal recorded by digital oscilloscope for studied samples we notice:

glass has highest peak, while onion has the lowest one and that mean onion absorb most of the light and glass has high reflectivity. Polymer has a short period (1.68µs), which lead to high frequency. SNR (backscattered power divided by the noise equivalent bandwidth of the detection) for the recorded signals is very low for carbon and onion, while glass and pyrex have the biggest value.

Table 1: illustrates the samples results calculated from the above figures (4-9).

Samples	R R(µm) Longitudinal resolution (depth resolution)	ΔL_B(µm) spatial resolution in longitudinal direction
Glass 1.0mm	0.2758	0.2068
Glass 1.2mm	0.3647	0.2735
Pyrex 0.1mm	0.556279	0.4172
Polymer	0.152973	0.1164
Carbon	0.17064	0.128
Onion	0.1412	0.1059

According to the above table, longitudinal resolution is higher than transverse resolution for all samples. Pyrex has the biggest resolution (longitudinal resolution 0.55627 µm, transverse resolution 0.4172 µm) and the minimum for Polymer. From the above results we noticed that; the constructed optical coherence tomography system (OCT) can be used to determine the depth resolution and transverse resolution [19] in longitudinal direction with good performance for different samples, beside that the constructed OCT is easy to use and efficient in performance. From the variation of the intensity with distance, in order to obtain a spectral tomography of the objects [23,24], optical properties can be determined by fitting linear or logarithm function. Figures (10-14) show this variation, and table (2) illustrates the optical properties for different samples.



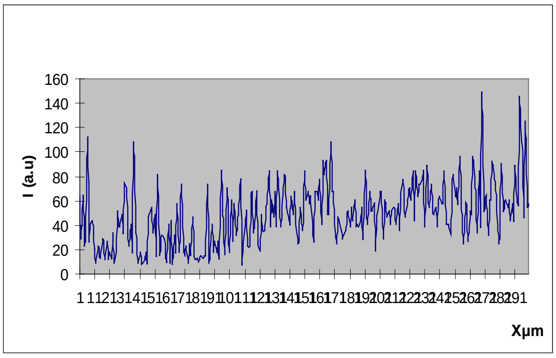
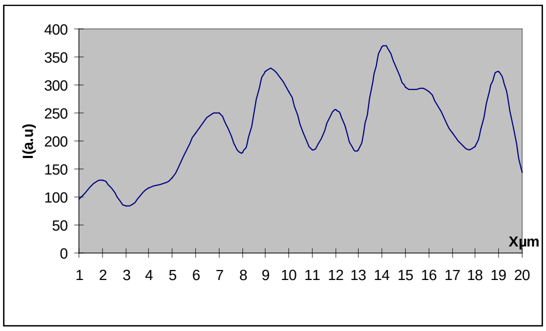


Figure 10: intensity of the backscattered light as a function of depth for glass 1mm

Figure 11: intensity of the backscattered light as a function of depth for glass 1.2mm



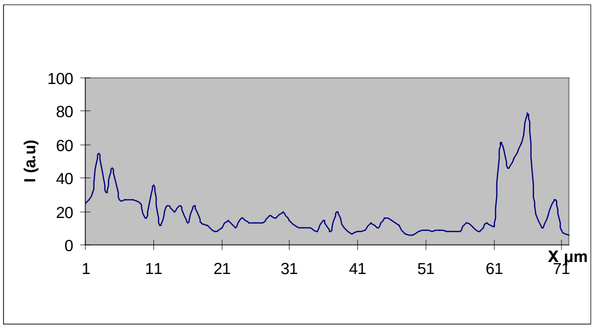


Figure 12: intensity of the backscattered light as a function of depth for pyrex

Figure 13: intensity of the backscattered light as a function of depth for polymer

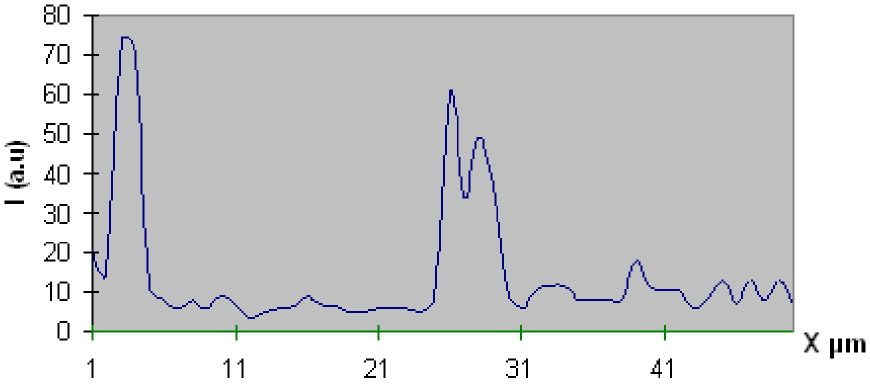


Figure 14: intensity of the backscattered light as a function of depth for carbon coating

Carbon and onion have low backscattered signal and glass, Pyrex have a bigger value due to low SNR, while polymer has value between them.

Table 2: Samples optical properties

Object type	Penetration depth (mm)	Absorption coefficient (mm^{-1})	Attenuation coefficient (mm^{-1})	Scattering coefficient (mm^{-1})
Glass1mm	0.037	20.382	27.02702703	6.645027027
Glass1.2	0.070	13.860	14.286	0.426
Pyrex	0.060	13.750	16.667	2.917
Polymer	0.065	13.860	15.385	1.525
Carbon	0.024	36.474	41.667	5.193

Object type	Reduced scattering Coefficient (mm^{-1})	Reduced attenuation coefficient (mm^{-1})	Reduced penetration depth (mm^{-1})
Glass1mm	13.290045	33.672045	0.029698
Glass1.2	0.8514	14.7114	0.65
Pyrex	5.834	19.584	0.051062
Polymer	3.049	16.909	0.05914
Carbon	10.385	46.859	0.02134

From the above tables we can notice that the constructed (OCT) can be used for determination of the optical properties [24] of the different samples successfully.

To prove the good performance of the constructed OCT, system the results were compared with another results gained by a Photoacoustic system for the polymer and carbon coating samples.

Figure (15) shows the recorded photoacoustic signals, which were generated after laser excitation of the polymer and carbon coating.

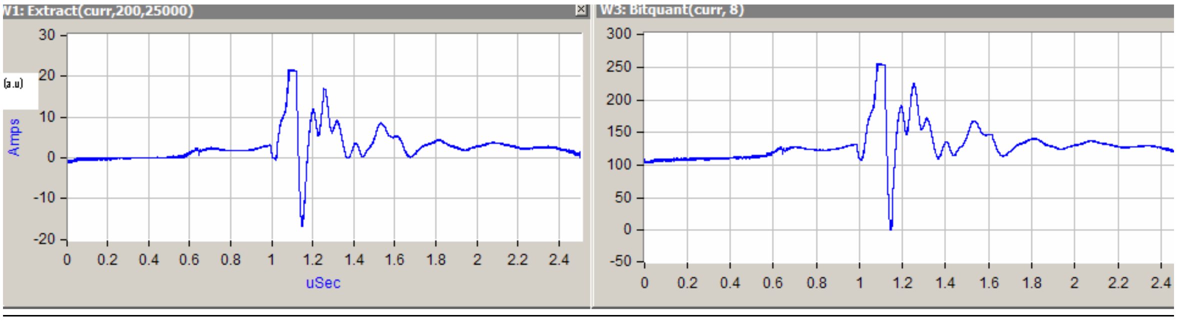


Figure 15: photoacoustic response for polymer and carbon

The optical absorption coefficient of the samples can be determine from photoacoustic signals (PA) by fitting the logarithm of the (PA) signal amplitude as a linear function of time[25] as in (OCT). From the above results and discussions one can notice that both techniques (Constructed OCT & PA) have the ability to gain spectrum for different samples, beside that, samples optical properties can be determined by using both techniques.

4. Concolutions

From the obtained results one can conclude that:

1- The constructed (OCTS) is a demand for gaining insight into functional parameters of tissues or materials.

2- It has potential to extract all optical properties.

3- The results showed that the tomographic system can be used as diagnostic systems with high resolution.

4- (OCTS) tomographic technique can be used to get two & three dimensional image information of internal structure of the object

5- The technique has a potential to determine the thickness and the optical properties for different samples.

6- The constructed technique has no ionizing effect compared with another tomography imaging (nuclear rays).

5. Recommendations

The constructed Optical coherence Tomography system can be modified to be used with invivo measurements by using optical fiber, sources with partial coherence like Superluminescent diode (SLD). Automatic scanning system can be used to perform good scanning for samples, so that information from different layers inside the samples can be gained with good resolution.

Acknowledgements

My deep gratitude and thanks to National institute of Laser Enhanced Science, Cairo University staff

References

[1]. Marc Boone,1,* Mariano Suppa,1 Makiko Miyamoto,1 Alice Marneffe,1 Gregor Jemec,2 and Veronique Del Marmol1, “In vivo assessment of optical properties of basal cell carcinoma and differentiation of BCC subtypes by high-definition optical coherence tomography”, Biomed Opt Express, 7(6), pp 2269–2284, 2016 Jun 1.

[2]. Christoph K. Hitzenberger, Manfred Kullhavy, Franz Lexer, Angela Baumgartner, and Adolf F.Fercher, “In vivo intraocular ranging by wavelength tuning interferometery”, San Jose, California, SPIE Vol.3251, (1998)

[3]. Mehreen Adhi and Jay S. Duker, “Optical coherence tomography – current and future applications”, US, National Library of Medicine National Institutes of Health 2013

[4]. David Turbert, “What Is Optical Coherence Tomography?”, American Academy of Ophthalmology, (2018)

[5]. J. B. Thomsen, B. Sander, M. Mogensen, L. Thrane, T. M. Jørgensen,G. B. E. Jemec, P. E. Andersen , Optical Coherence Tomography: Technique and Applications, springer-Verlag Berlin Heidelberg 2009

[6]. A.F. Fercher and C.K. Hizenberger “Optical Coherence Tomography in Medicine”, Berlin, optical science VoL-l4 Springer, (1999)

[7]. A.F. Fercher, W Drexler, C.K.Hizenberger and T Laser “optical principle and application”, Electronic Journals (2003)

[8]. Lihong V.Wang and Qimin Shen, "Sonoluminescence Tomography of Turbid Media", San Jose,California, SPIE Vol.359, (1999)

[9]. E.wolf, "On the fundamental theorem of diffraction tomography", SPIE, San Jose, California (1993)

[10]. Markus Laubscher, Mathieu Ducros, Boris Karamata, Theo Lasser and Rene Salathe, "Vidio rate three dimensional optical coherence tomography", Optics Vol 1, OSA (2002)

[11]. Tony Ko, Ingmar Hartl, Wolfgang Drexler, Ravi Ghanta, James Fujimoto, "Ultrahigh resolution optical coherence tomography for quantitative topographic mapping of retinal and intraretinal architectural morphology", SPIE 4619, San Jose, California (2002)

[12]. Hrynchak P1, Simpson T, Optical coherence tomography: an introduction to the technique and its use, Optom Vis Sci. 2000 Jul;77(7):347-56.

[13]. Kaname Uno, Tomoyuki Koike, and Tooru Shimosegawa , Recent development of optical coherence tomography for preoperative diagnosis of esophageal malignancies Biomed Opt Express v.7(6),US National Library of MedicinmNational Institutes of Health 2016

[14]. Adolf F. Fercher, "Optical Coherence Tomography", journal of biomedical opticas Vol 1 (1996) Maciej Wojtkowski, Raniner leitgeb, Andrzej Kowalczyk, Adolf Fercher, "Fourier domain OCT imaging of human eye in vivo", SPIE 4619, San Jose, California (2002)

[15]. Huang D, Swanson EA, Lin CP, et al. Optical coherence tomography. Science. 1991;254:1178–1181

[16]. Sull AC, Vuong LN, Price LL, et al. Comparison of spectral/Fourier domain optical coherence tomography instruments for assessment of normal macular thickness. Retina. 2010

[17]. Cheryl D. DiCarlo, W.P. Roach, Donald A. Gagliano, Stephen A. Boppart, Daniel X. Hammer, Ann B. gox and Jameg G. fujimoto, "Coparison of optical coherence tomography imaging of cataracts with histopathology", journal of biomedical optics Vol 4 (1999)

[18]. James G. Fujimoto, "Optical coherence tomography", applied Physics, Paris,1v,pp1099-1111, November 2001.

[19]. Jian yu lu, Jiqi Cheng, and Brent D. Cameron, "Low sidelobe limited diffraction optical coherence tomography", SPIE 4625, San Jose, California (2002)

[20]. Paul Dean, Mark R. Dickinson, Dave P. West, "Optical coherence tomography using a photorefractive polymer composite", SPIE 4956, San Jose, California (2003)

[21]. D.huang, E.A. Swanson, C.P.Lin, J.S. Schuman, W.G. Stinson, W. chang, m.R. Heee, T.Flotte, k.Gregory, C.A. pulifito, and J.G. Fujimoto, "Optical Coherence Tomography", Science 254 (1999)

[22]. R.Leitgeba, M.Wojtkowskib, C.K.Hizenbergera, A.F.Ferchera, M.Stickera u, A.Kowalezykb, "depth resolved spectroscopy by frequency domain optical coherence tomography, SPIS, vol.4160, pp.57-61, 2000.

[23]. Christoph K. Hitzenberger,"optical measurement of the axial eye length by laser Doppler interferometery", investigative ophthalmology & visual science, vol. 32, No. 3, March 1991

[24]. Y.A.Badr1, M.E.Gadallah2. M.F.Hassan3, Y.H.SlSharkawy4, laser induced photoacoustic imaging for characterizing tissue equivalent phantoms, presented at the 2nd Cairo international biomedical engineering conference, 2004.