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RESEARCH ARTICLE

DISCRIMINATION OF SKIN MICRO-TEXTURES USING INTELLIGENT LASER SPECKLE TECHNIQUE.

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Abstract

When human skin surface is illuminated by a coherence light, the interference of the resulting scattered wavelets present a particular intensity distribution, making the surface appear to be covered with a fine granular structure of dark and bright spots is known as a “Bio-speckle pattern”, (or signature). This signature can then be recorded by using a high digital CCD camera, which utilizes the micro-textures of skin to create a “laser speckle image”. Intelligent Laser speckle technique permanently used for examining optical roughness of different surfaces with features dimensions in the range of visible light wavelength. Special parts of normal and diabetic human skin, also a model skin of silicon layers, and layers made of medical spray (Opsite-moisture vapour permeable spray dressing) on harmed skin has been used as test rough objects. Where skin surface roughness is an important parameter for early diagnostic of some diseases that are invisible to the human eye. Especially for diagnosis of the systemic diseases where the skin does not yet exhibit their visual effects by its surface changes. In this work, intelligent laser speckle optical technique was used to record different surface roughness with features dimensions of human skin and different types of model skin. This technique is simple where it composed of a laser source and a high-resolution CCD camera. This technique is fast and non-contact direct method based on laser speckle contrast measuring technique for detecting a micro-skin degree of roughness in-vivo.

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Introduction:-

When an optically rough surface is allowed to be illuminated with light has a high degree of coherence, the scattered light presents a particular variable intensity distribution spot, making the surface appear to be covered with a fine granular structure. This structure consists of dark and bright spots distributed in a random way. It is known as a laser speckle pattern, in order to observe such speckle pattern a high-resolution CCD camera will be used at a certain distance from the object.[1][2]

The technique relies on laser speckle obtained by the interactions between coherent monochromatic radiations and the tissues under study. The speckle displayed from laser scattered of human skin and skin model indicates most information about its properties and surface roughness. The fluctuation of the resulting speckles from multiple

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scattering from skin surface can also display information about the physiological activity of living tissue in the human skin.

The speckle pattern resulting from the rough surface becomes an important issue in developing laser medical diagnostic techniques. The human skin surface roughness analysis retains of great importance also in derma-cosmetics and cosmetic science to be evaluated. The technique relies on laser speckle obtained from the interactions between coherent monochromatic radiations and the tissues under study. The contrast values of such speckle images were measured and instantaneous contrast map of the skin model was computed.[3][4]

Many data and information about the skin and diseases found in the human body can be obtained by the image from the surface of the skin, by using a laser speckle contrast image technique. This application is easier, cheaper and is not harmful to human skin surface than other applications. This application used also in, static and dynamic displacements [5], strain measurements [6], phase measurements [7] and temporal speckle analysis to determine biological behavior [8]. investigated the degree of sugar in the body by analysis this bio-speckle image will be studied in our work, and then we can treat the body in a quick way to avoid diabetes. But we initially used artificial skin model to simulate the human skin to do the testing of absorption and scattering of this skin directly by using the spectrometer.

A relationship between the laser speckle and surface roughness of the human skin will be studied applying laser speckle contrast image technique, which is the most important non-contact technique it didn't harm the skin. And has more sensitivity for measuring the deformation happens to the skin when exposed to any changes by perfectly way such as happened when the skin has diabetes and the level of glucose is high all over the day. Then , The optical properties (absorption, scattering, anisotropy, scattering, refractive index) of various tissues measured to investigate the impact of different environmental factors (chemical, agents drugs, UV-radiation, temperature, etc) at many wavelengths.

Diabetes mellitus is Characterized as a serious illness It is produced due to elevated plasma glucose. Or occurs inasmuch as the pancreas cannot produce insulin or insulin which produces insufficient and cannot work properly in the body, where Insulin is produced by the beta cells in the pancreas (the organ that produces insulin). resulting in the accumulation of glucose in the blood, leading to high levels of glucose in the blood, causing health problems linked to diabetes. Altered skin wound healing is a common cause of morbidity and mortality among diabetic patients. There are two types of diabetes 1 and 2. Diabetes can affect every part of the body, including the skin. As many as one-third of people with diabetes will have a skin disorder caused or affected by diabetes at some time in their lives. In fact, such problems are sometimes the first sign that a person has diabetes. Luckily, most skin conditions can be prevented or easily treated if caught early. Some of these problems are skin conditions anyone can have, but people with diabetes get them more easily. These include bacterial infections, fungal infections, and itching. Other skin problems happen mostly or only to people with diabetes. These include diabetic dermopathy, necrobiosis lipoidica diabetorum, diabetic blisters, and eruptive xanthomatosis.[12]

Speckle contrast

The difference in brightness between the bright and dark areas of the speckle image is known as the contrast of the speckle from the rough surface. Different random speckle patterns were formed due to laser scattering from the skin rough surface. These patterns were recorded by using a high-resolution digital camera, the contrast C of different speckle patterns were calculated using a software program, where:

$$C = (I_{\max} - I_{\min}) / I_{\max}$$

Where C is the speckle contrast of a skin surface, I_{\max} is the maximum pattern intensity and I_{\min} is the minimum pattern intensity. Here the speckle contrast contains salutary information on the physical parameters as a light source and scattered surface characteristics The relation between the calculated contrast of laser speckle patterns and the different thicknesses of artificial skin was presented. The contrast of the speckle pattern is proportional to the surface roughness where the very smooth surface produced no speckle at all so it has no contrast value to be calculated. But in another way the rough surface such skin has a contrast value due to the scattered happens from the skin surface. If the scattered is completely random, the value of the contrast is $C=1$, obtained fully developed speckles. But if the contrast is between $0 < C < 1$, obtained a partially developed speckle field. The relationship

between speckle contrast and surface roughness is linear until reach to saturate. The saturation will happen when the contrast converges to unity.[9]

Speckle grain size:

speckle size is essentially controlled by the aperture size of the recording camera. When laser speckle is used, the wavelength of the laser beam, the f/number of the recording lens and magnification of the system determines how small the laser speckles can be generated. When white light speckle is used, the size is determined by the resolution of the recording lens. no speckle smaller than half of the wavelength of the radiation can be recorded.

The size of the subjective speckle δ produced using such set-up is given approximately by:

$$\delta \approx 0.6 \frac{\lambda}{N.A}$$

Where λ is the wavelength of the coherent light source and N.A is the numerical aperture of the image forming lens . N.A = r/v where r is the radius of the lens and v is the distance from the lens to the screen.[10]

Experiment:-

The optical parameters of human skin

Biological tissue of the skin consists of three main parts figure (1). The superficial, composed of epithelial tissue, is the epidermis which is. The deeper, connective tissue portion is the dermis. And the hypodermis. Light is reflected or refracted on the skin surface, as well as elastically and in-elastically scattered and absorbed along the way of its path in the skin. Also, the skin exhibits a combination of specular and diffuse reflection.[13] the skin surface mostly reflects about 5–7% of the incident light. For different human skin components, the refractive index in the visible and near IR wavelength range varies from a value ~ 1.35 for interstitial fluid to 1.55 for the stratum corneum the top layer of the epidermis. In the wavelength range of 400–1100 nm, values for its scattering and absorption coefficients both decrease with wavelength adapted from Yang et al [14], Figure (2).

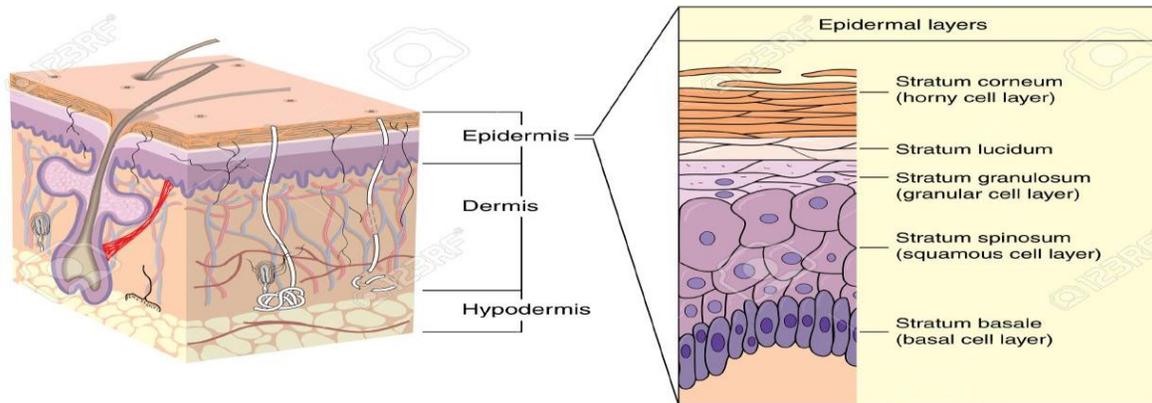


Figure 1:-three layers of human skin

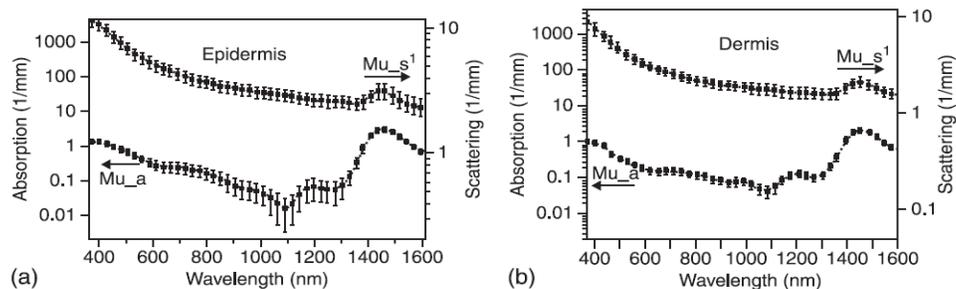


Figure 2:-optical properties of epidermis (adapted from Yang et al. [15] with permission)

In figure (2) show (a) Optical properties of the epidermis. Triangles – reduced scattering coefficients, bars – standard errors. Averaged over eight samples. (b) Optical properties of the dermis. Triangles – reduced scattering coefficients, bars – standard errors (adapted from Yang et al.) [15]. Which help for our work to be a comparison with the skin model of silicone where it very close to the result of human skin.

Bio-tissues includes micro and macro-inhomogeneities, like blood vessels, skin appendages or tumors. The sizes of cells and tissue structure elements have a different size from fractions of nanometers to hundreds of micrometers. The propagation in an inhomogeneous medium with absorption, a photon changes its direction due to reflection, refraction, diffraction, or scattering, and can be absorbed by an appropriate molecule on its path. Due to obtain a very good speckle pattern needed a more scattered light when a monochromatic laser beam allowed to an incident on the surface of human skin absorption and scattering will occur. Once the light reaches the skin part of it is absorbed, part is reflected or scattered and a little part might be transmitted. Absorption and scattering are studied in vitro by using a skin model of silicone layers figure (3).

Absorption: As the light travels through tissue, an amount of this light can be absorbed by the skin and enter the deeper layer (dermis).

Scattering: Light scattering means a change in the direction of propagation of light in a turbid medium caused by reflection and refraction by microscopic internal structures. Such small structures, which are smaller than or comparable to the wavelength of propagating light, are commonly called scatters, which can be defined as an inhomogeneity or a particle of a medium that refracts or diffracts light.

Penetration depth: Penetration depth is a measure of how deeply light can penetrate into skin layers. It is defined as the depth at which the intensity of the radiation inside the skin falls to $1/e$ of its original value. Knowledge of the penetration depth is essential for evaluation of interrogation volume while measuring optical properties of tissue.

The optical properties of model skin must be studied to obtain a lot of information about the skin model and allowed to select the appropriate wavelength to use in our work which can be simulated with the human skin case. Where the best liberty for wavelength is the right foundation for studying skin surface characteristic [11], The work described in this part was aimed to find a suitable laser to provide discrimination between normal and abnormal skin surface. when light allowed to an incident on the rough optical skin surface it will be reflected by two different way diffuse and specular reflection figure (4), where the specular reflection has the same angle of an incident but the diffuse reflection has a different angle according to how much the skin surface is rough. Here we need to study the diffuse reflection to obtain all scattered waves from the skin surface. we used different types of laser to know which one achieves the best penetration within the skin to get the largest amount of reflected from the skin and study the ability of light to penetrate a tissue, to give us more information about the characteristics of skin and its surface roughness.



Figure 3:-skin model of silicone used to simulate a human skin in laboratory

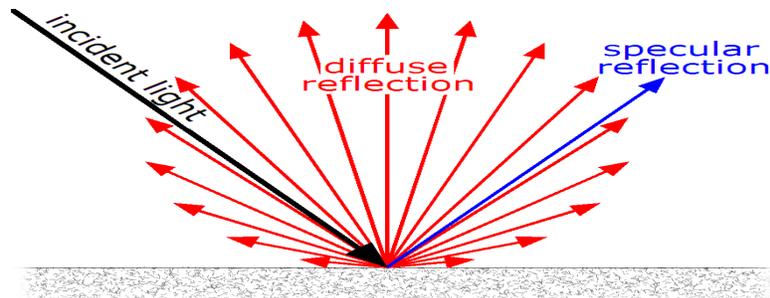


Figure 4:-incident light on skin surface will be reflected by two different way

Procedure

The developed laser speckle technique is shown in figure (5) is composed of A He-Ne laser source with wavelength 632.8 nm and power (10 mW), is allowed to an incident on the surface of the human skin which considered as an optically rough surface. then, we obtain dark and bright spots which be in a heterogeneous manner called “Bio-speckle” pattern. This bio-speckle carry multiple information about the surface of the human skin and we can obtain that information by analyzing the image using a software program. In order to avoid the speckle contrast measurement error which is caused by environmental light, all measurements are made under the darkness. The collimated He-Ne laser is used in this experiment. The laser beam quality measured 50 cm away or more. the beam propagates and falls on the CCD camera. The speckle image recorded by the CCD camera and the speckle contrast is calculated by using a software program.

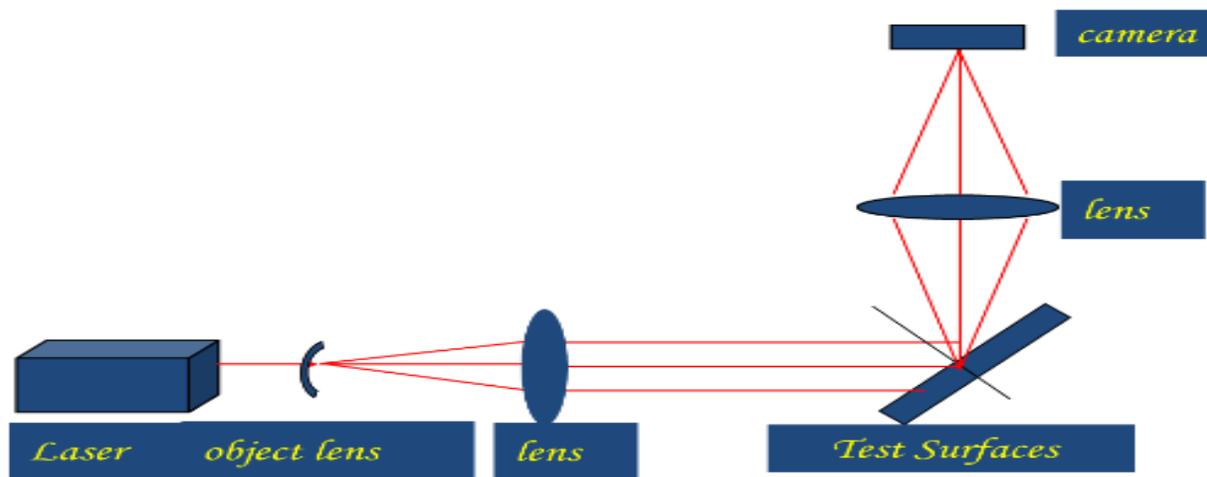


Figure 5:-Optical scheme for the speckle measurement setup of skin

Model Sample preparation:

First, the samples that made from silicone were prepared in our laboratory. The samples were scraped with different thickness using the microtone and were cutting using wax at 60 ° C at a different thickness (50, 70, 80, 90, 100, and 180 μ m) it was deposited on a glass slide To make it easy to work on it figure(6). Second, these samples were filmed using laser speckle technique using different wavelengths (632.8, 540, 645) nm. Then a different section of an artificial skin was cutting and obey to mechanically abrasion using abrasive stone with varying degrees of roughness (60, 80, 320, and 400) μ m, and then recorded a resulting laser speckle before and after the roughing process to identify the difference in the difference between before and after the obvious on the samples through the images shown in figure (8-9) , the resulting speckle and their intensity distribution is represented. A relation between the roughness of the skin model and its resulting contrast is studied to obtain a standard curve is shown in figure (8) related to the actual human skin causing the difficulty of making this test in-vivo on human skin. Then Direct imaging of the live normal and diabetic human skin in front of the speckle system is shown in figure (10-13) and imaging for one shot, where a healthy and diabetic people were photographed in a random manner throughout the day and diabetes was measured using a blood glucose monitoring system GS100 with high accuracy fig (16).



Figure16:-a blood glucose monitoring system GS100

Results and Discussion:-

After applying the artificial skin to the laser speckle contrast image technique and obtained a laser speckle from different laser sources. we found that The fluctuation of the speckle contrast displays the effect of skin surface occur due to the different thickness (50, 70, 80, 90, 100, and 180 μ m) by using different wavelengths of (632.8, 540, 645) nm). using the He-Ne laser is a good result by comparison with another diode lasers which has a low coherent laser speckle. A relationship between the laser speckle contrast resulting from those samples and with their thickness by using laser speckle technique in a completely dark room to obtain accuracy of an image of bio-speckle extracted from the skin surface is presented .

a relationship between the degree of sugar of the human skin and the value of the resulting variation laser speckle contrast of the skin surface of the living person for four samples is studied in figure (10-13) taking into account the pores and hair found in the skin.

The laser speckle contrast of skin at different roughness before and after applying to a rough machine, and before and after exposure to an increase in blood sugar using different laser diodes

using He-Ne laser of wavelength 632.8 nm and three laser diode of wavelength (532, 490, and 635) nm. The fluctuation of the speckle contrast displays the effect of skin model layers thickness. This means that each skin layer expresses itself through different surface roughness. using red laser diodes speckle, the contrast increases by increasing the thickness of the skin and vice versa using the blue and green laser diodes speckle. Figs. (8-9) represented the relationship between the laser speckle contrast of skin and its thickness before and after applying to a rough machine. After making roughness of silicon layers skin model found that as the roughness increase the contrast value would be decreased due to the decreasing of the maximum intensity, as knowledge, the contrast depends on Direct proportion on the intensity value. This means that the higher the roughness of the surface of the skin, the more the topography on the skin and then the less scattered light from the surface. therefore, find that the bright spots less than dark ones of speckle image, so the value of the contrast is less and conclude that the more roughness of the surface the less variability in the speckle contrast. As frequent, the roughness is dependent on The total value of the speckle contrast from the surface of human skin. Then, The same results when the skin is diabetic where diabetes or raising of degree of suger in the blood will change the roughness of the skin surface and topography and that will be studied by doing the same process on the skin directly. Two types of people with type 2 diabetes were tested for men of the sixth decade of age and skin imaging using the intelligent laser speckle technique at the temperature of the room in the morning repeated the same process every hour and measured the degree of sugar, Measure the blood glucose level using a blood glucose monitoring system GS100 with high accuracy, where the measurement of sugar at the beginning and the person fasting, and then after breakfast and daily activity with the passage of an hour in each speckle image and take the degree of sugar then make a relationship between the degree of sugar over time and the intensity of variability of the contrast resulting from the diabetic skin surface. We note that there is a strong relationship between the degree of sugar and the speckle contrast resulting from the surface of human skin. Consequently, the indication from the relationship shown in figure (10-11) was that the higher the degree of sugar in the blood the greater the value of the speckle contrast resulting from the surface of the skin. where two areas of skin were tested hand and forearm at the circumstance. The same steps repeated for other two-person samples presented in figure (12-13) whosoever, also as the degree of sugar increase the speckle contrast increase. So the roughness of the skin in all ways decreases if the blood glucose level increases. This is a good innuendo to know the degree of blood sugar once after known the roughness of the skin surface using intelligent laser speckle technique with directly way to the skin surface. From these results, we can treat the condition of the person with

diabetes early to protect the person from the symptoms of inflation in the disease and prevent the patient from reaching difficult situation and deterioration of the disease.

The optical properties of this model skin surface are measured using 10 mW He-Ne laser at wavelength 633 nm and optical spectrophotometer (ocean optics) with a spectral resolution (the increment step) of 0.1 nm at central wavelength. Spectral bandwidth was 1.2 nm, and wavelength accuracy was 0.6 nm. Average of ten scans were taken on each sample as its absorption spectrum. The light beam was collimated with a spherical lens of 150mm focal length before an incident on the skin model sample [11]. In Figure(14) and (15). we find the best reflection area of the skin surface at the area of (from 635 to 640) nanometer which gives The best speckle image obtained when a proper usage of a laser source gives less absorption and higher dispersion. A Helium-Neon laser is a good coherent source presents high resolving speckle patterns to the human skin.

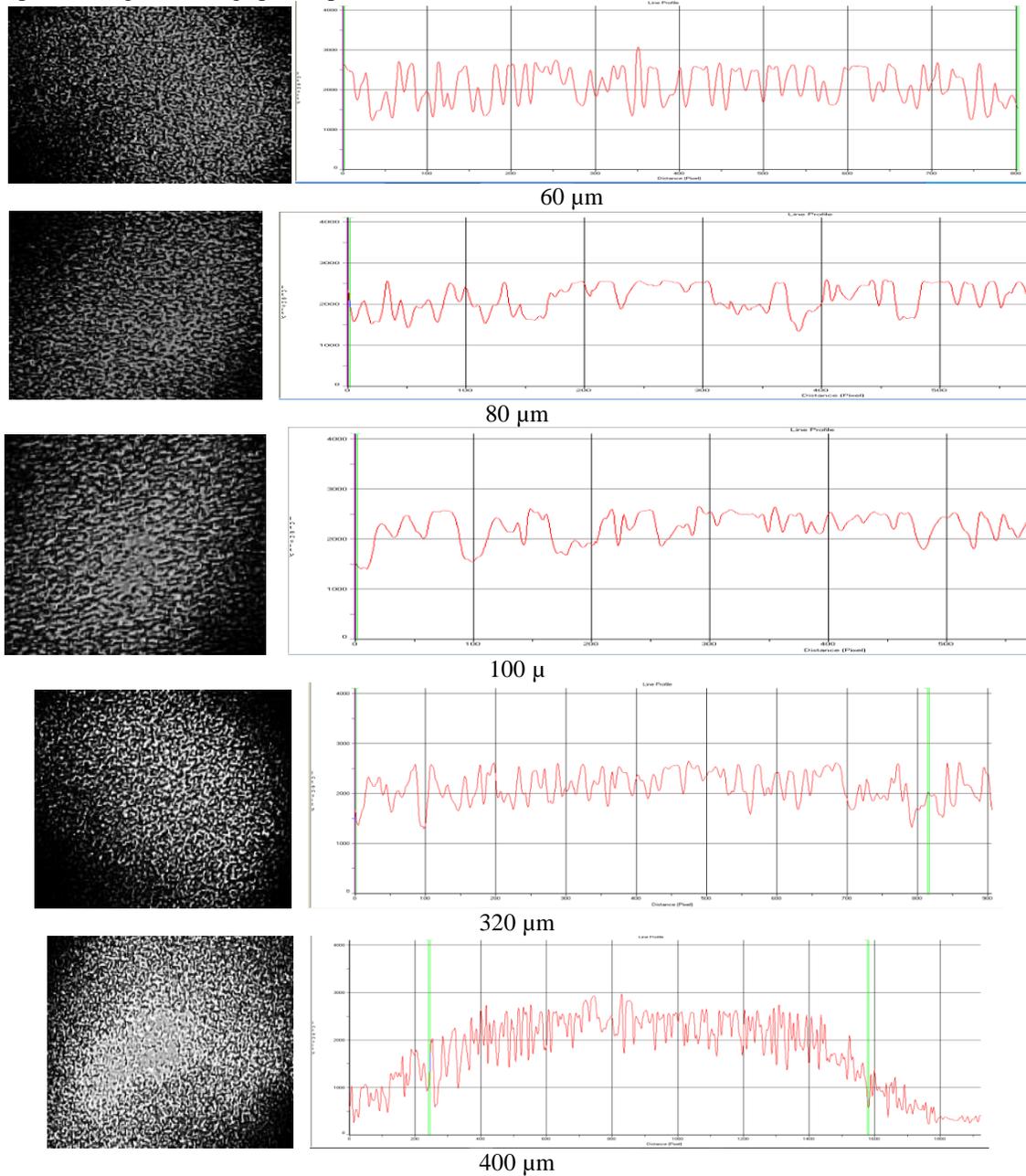


Figure 7:-Bio-speckle pattern and intensity distribution of silicone specimen with different surface roughness (60,80, 100, 320, 400 μm) using green laser diode

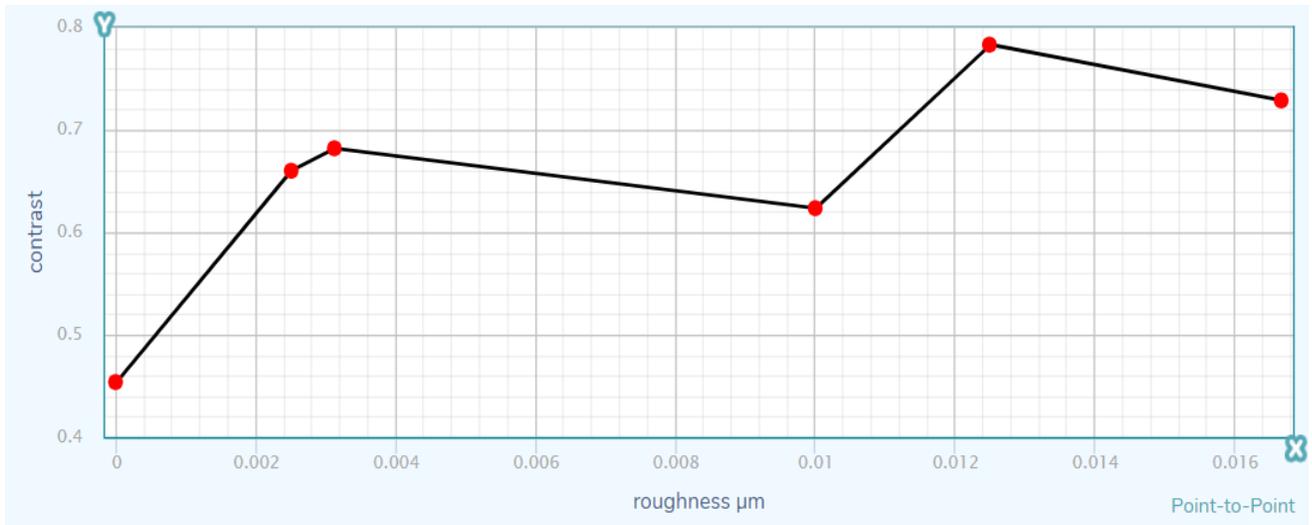


Figure 8:-relation between the roughness of silicon layers and its speckle contrast after rough machine with He-Ne laser with standard deviation (0.10339)

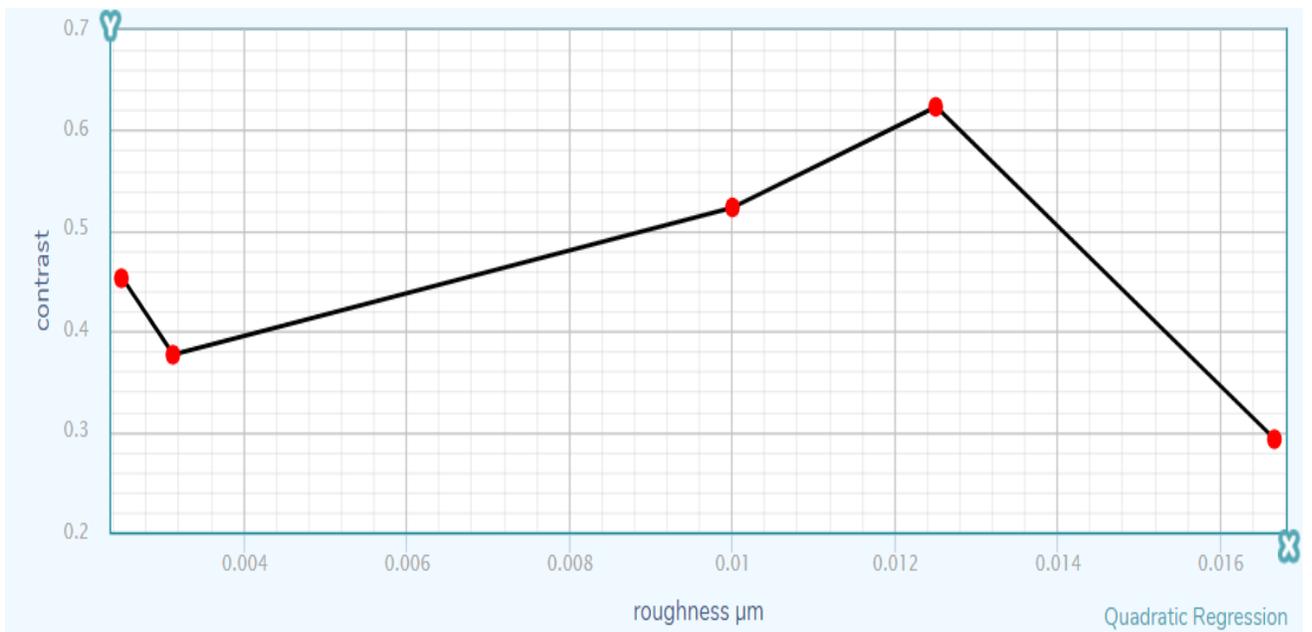


Figure 9:-relation between the roughness of silicon layers and its speckle contrast before rough machine with He-Ne laser with standard deviation (0.114427)

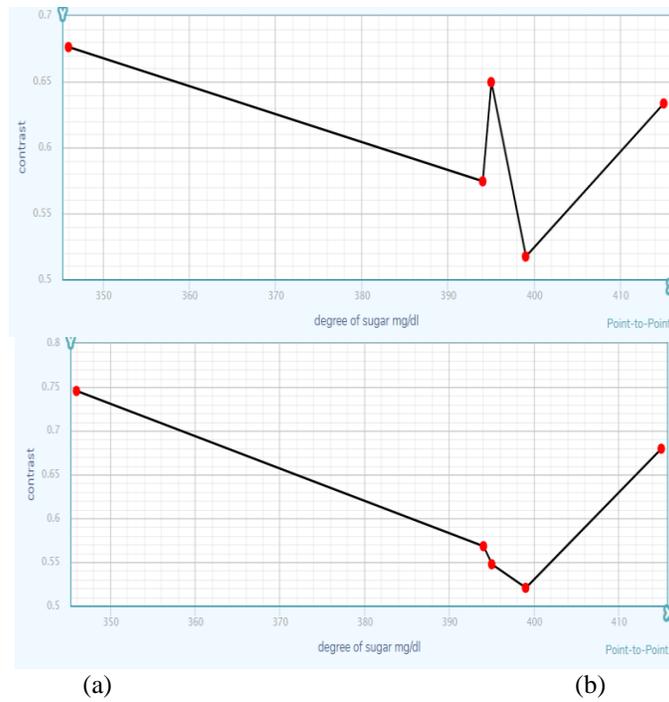


Figure 10:-relation between the degree of sugar (mg/dl) of live skin and the resulting speckle contrast of forearm (a) and hand (b) of sample 1 using He-Ne laser

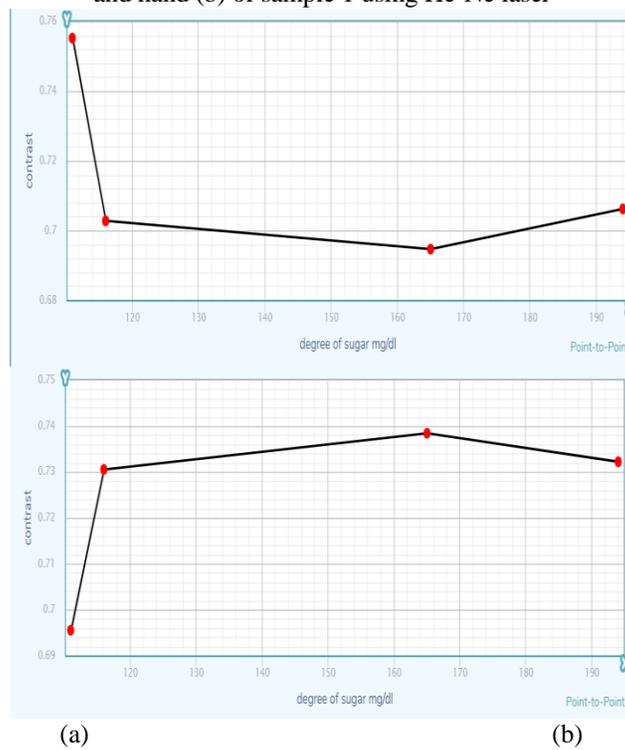


Figure 11:-relation between the degree of sugar(mg/dl) of live skin and the resulting speckle contrast of forearm (a) and hand (b) of sample 2 using He-Ne laser

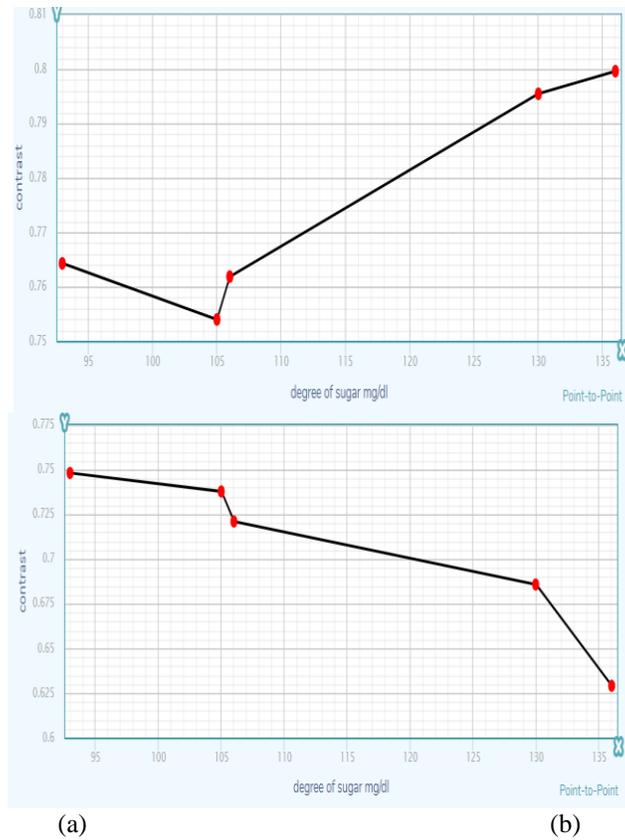


Figure 12:-relation between the degree of sugar(mg/dl) of live skin and the resulting speckle contrast of forearm (a) and hand (b) of sample 3 using He-Ne laser

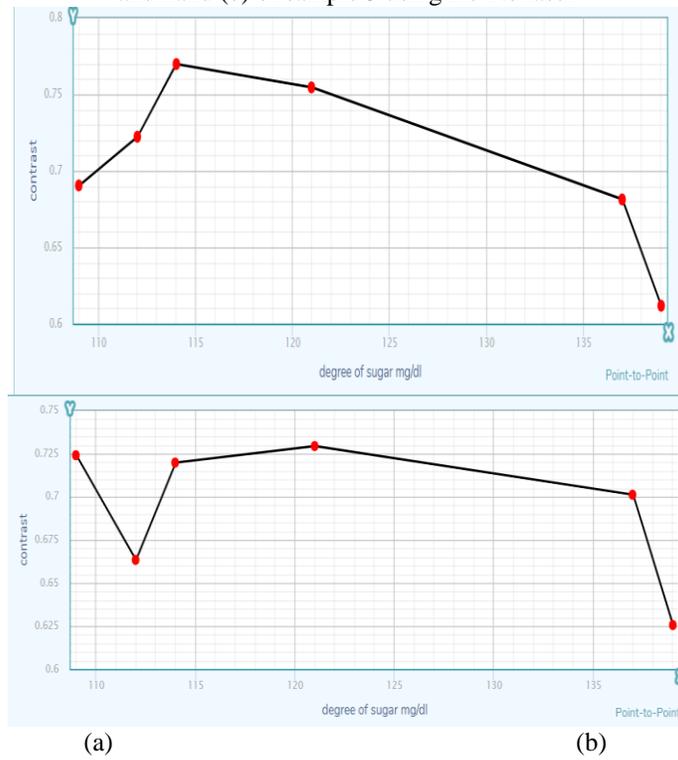


Figure 13:-relation between the degree of sugar(mg/dl) of live skin and the resulting speckle contrast of forearm (a) and hand (b) of sample 4 using He-Ne laser

Results of Optical properties of silicon skin model :

Absorption coef.

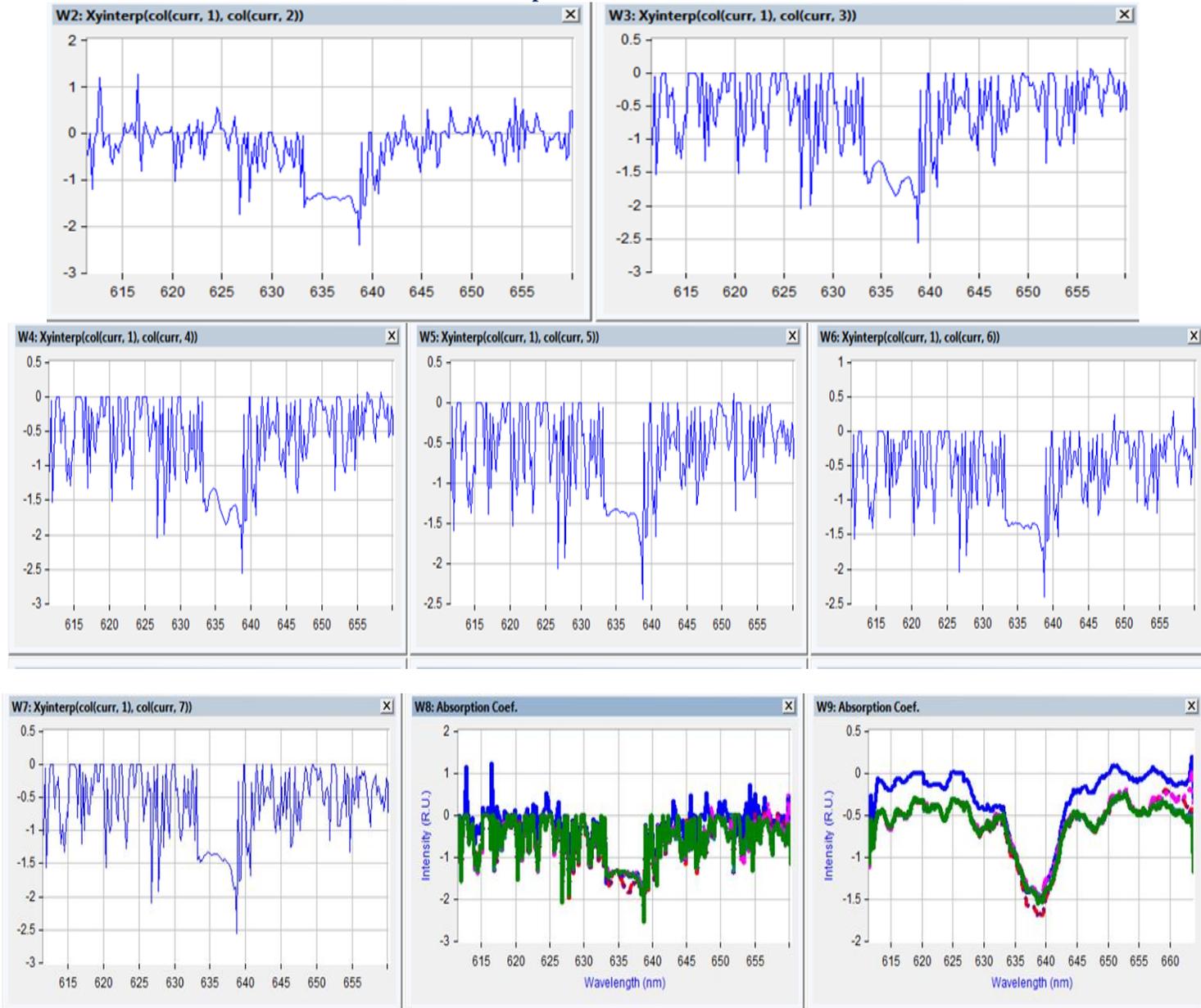
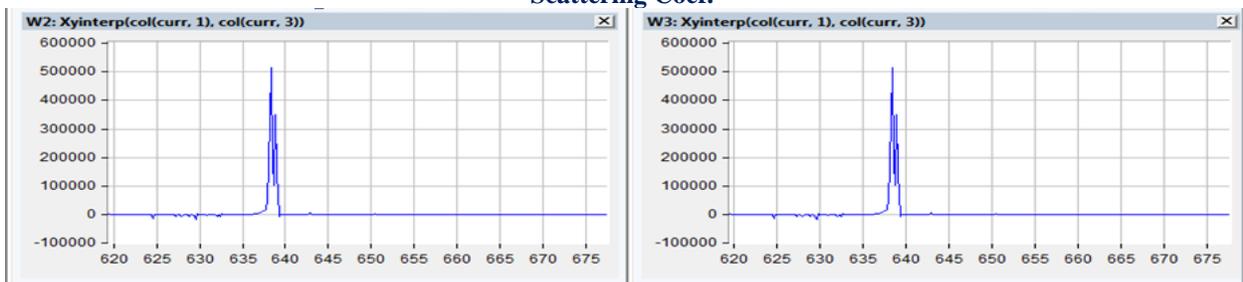


Figure14:-the measured absorption coefficient at 633 nm for scanned different six samples illustrated in (w2, w3, w4, w5,w6, w7) and the averaging of the measured spectral in(w8, w9) for a skin model of silicone layers

Scattering Coef.



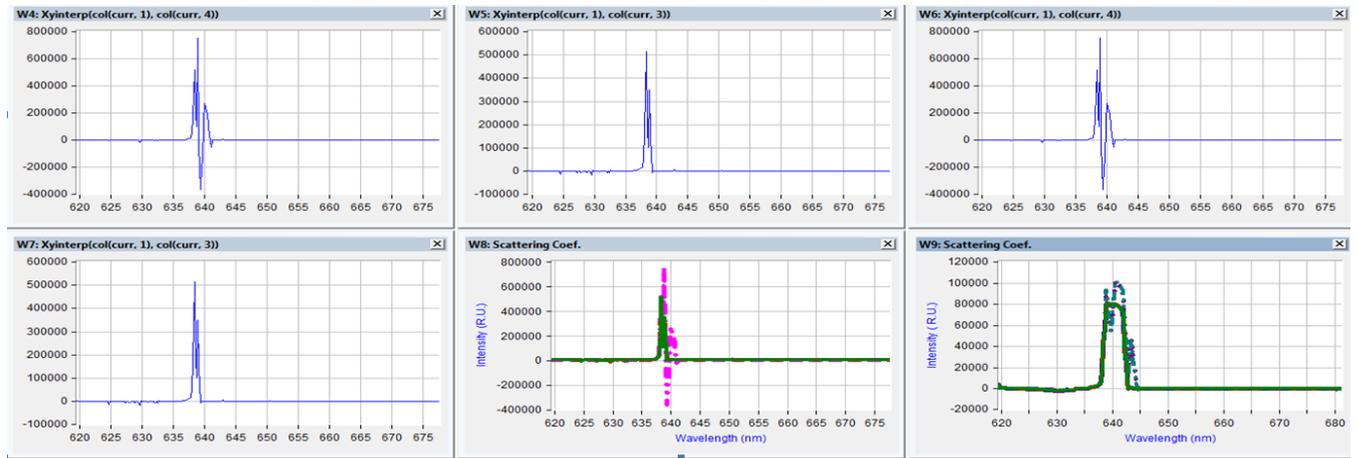


Figure 15:-Representative scattering coefficient spectra acquired from skin model samples

Conclusion:-

Intelligent laser speckle technique is a good technique to discriminate between micro-texture of human skin, after exposing to raising the degree of sugar in the blood. Where laser speckle contrast imaging can show the micro-changes happen in the skin surface topography easily by using a safety way as laser light, that incident on the human skin directly then the speckle patterns can be recorded to an analysis by a software program and image process. Therefore, the value of contrast with the degree of sugar of human skin can be plotting due to indicate the difference before and after increase the glucose in the human body. From the result, it's ascertained that as the degree of sugar in the human body is increase the resulting contrast value grow to increase. In forearm is more clear than in hand. So, the laser speckle contrast image is a sensitive technique to detect a diabetic early diagnostic. so the roughness of human skin is decreased and vice versa. Consecutively, the laser speckle enables to diagnostic the diabetic for people to recognize the disease rapidly and treat it before reaching a difficult situation.

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