An Overview and Biological Tissues Characteristics Using Optical Simulation Method

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Abstract **:-** A new low cost optical measurement system was developed for testing of biological soft tissues. Other technique creates backscattered light on a tissue surface by piercing three sets of small conducting optical fibres. The optical properties of the skin lesion was determined with the help of laser reflectometry. The result was compared with phantoms and simulation values to get accurate result.These profiles measured at various locations of the tissues on the forearm the corresponding optical parameters, the scattering (μ_s) and absorption(μ_a) coefficient and the anisotropy parameter g ,by matching these with profiles as simulated by Monte Carlo procedure were determined. A large area photodiode located below the tissue sample detects the light emitted from the set of optical fibres. Analog to Digital circuitry analyze the current signal from the Photo detector to determine the amount of light falls on tissue as simulated by the familiar Monte Carlo Simulation Method. Numerical results were compared with original results. These findings are necessary to trace the presence of any abnormal in the biological tissue.

Key- Words: 820nm Laser diode,Laser reflectometry, tissue equivalent wax, phantoms, optical fibres, ADC card and optical power meter.

1 Introduction

Fibre optic laser is the technique of using small diameter optical fibre for the measurement of optical parameters.Early detection[1],[2]. of tumors in the biological tissues [2]-[7] and other biological tissues by optical methods [8],[9] and their characterization by coherence tomography [10],[11]. The tissue properties [33] like absorption coefficient (μa), scattering coefficient (μs) and anisotropy parameter (g) are determined by various procedures [12], [13]. The application of lasers in medicine warrants thorough understanding and knowledge about moving photon tissue interaction mechanisms. Laser reflectometry is used to absorb tissue properties. When laser light is incident on a tissue, a fraction of this emerges as backscattered component at various locations on the tissue surface. The distribution of the backscattered component provides information on variation in internal composition of the tissue [14].Any new diagnostic or therapeutic technique needs thorough evaluation in terms of their potential limitations and patient safety prior to putting them into medical practice. In this , tissue equivalent optical phantoms can play an important role in evaluating a new optical diagnostic technique. The various phantoms models have been developed.

A sample phantoms like milk, India ink etc., do not allow uniform distribution of scattering particles within the medium and are not stable over long period of time. To overcome the difficulties associated with liquid phantoms, solid tissue equivalent phantoms come to the forefront. The solid stable phantoms are made of white crystalline paraffin wax mixed with wax color pigments. The diffuse reflectance profiles of various regions of the human forearm using laser multipurpose reflectometer are measured and matched with the reflectance profiles of the wax phantoms.

Monte Carlo simulation is a familiar method for simulating random process and has been applied to light-tissue interactions under a wide variety of situations [15]–[23]. Photon interaction with matter via scattering and absorption is stochastic in nature and can be described using Monte Carlo methods by appropriate weight absorption and scattering events [24]. Laser irradiation of skin using homogeneous and layered geometries [25],[26] has been effectively analysed using the Monte Carlo methods. In addition, for light propagation in tissue media, the results of the diffusion approximation have been compared to Monte Carlo simulation results.

2 Experimental Setup

2.1 Laser Reflectometry

The schematic of the multiprobe laser reflectometer is shown in Fig.1.

The part of the unabsorbed multiply scattered light reemerges from the skin's surface by diffuse reflectance [27].

Laser light beam of a 0.2 cm diameter from a laser diode module, which is a compact semiconductor laser diode of 3mW power, operating at 820nm, has been guided to the tissue surface by an optical fiber of 0.2 cm active diameter and 100 cm in length. The diffusely backscattered light from the tissue surface is collected by three optical fibres of the same dimensions as that of the source fibre. These three fibres have been arranged parallel to each

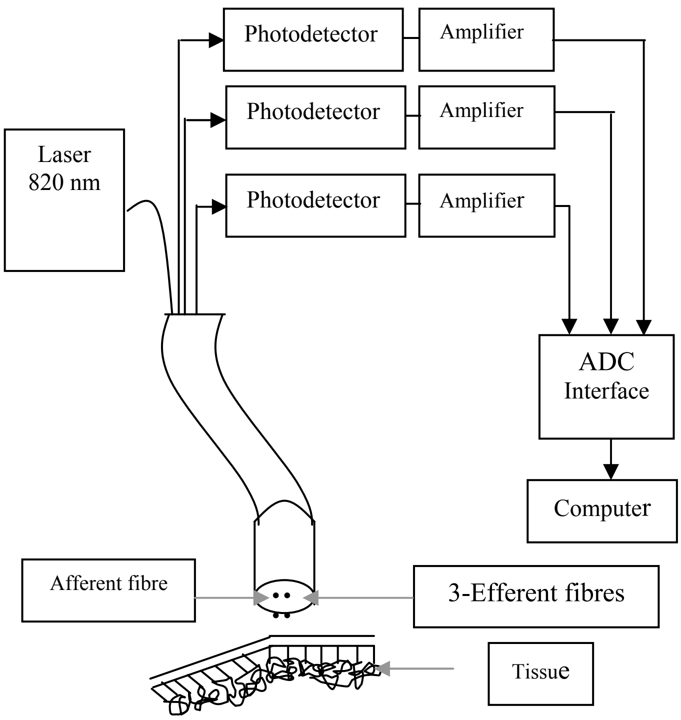


Fig.1. MultiProbe Laser Reflectometer

other in the measurement probe head with center-to-center separation of 0.2 cm. The diffusely backscattered light signals from the tissue surface, collected by optical fibres, have been converted into proportional current by three high speed ,low noise silicon p-i-n diodes. The current outputs of these photo detectors were converted into their proportional voltage by three operational amplifiers in the current voltage converter mode. These have been in turn digitized by a 12-bit analog-to-digital converter and interfaced to a computer for storage and getting a numeric result.

2.2 Tissue equivalent wax phantoms

To prepare phantom, paraffin wax, a white crystalline solid is used as a base material. The advantages with paraffin wax are that it can be made into any desired shape and geometry. It allows uniform mining of the wax colour pigments added for increased absorption, scattering and matching of the phantom's reflectance profile with that of tissues. Color palettes with different color concentrations of both pure colours as well as different colour combinations are made by varying the colour composition of the phantoms. The exact reflectance profile match with that of the tissue reflectance profile was obtained. The optical characteristics of the phantom analysis and the results are stored in computer and the data will be received later for making comparison.

3 Simulation Process

The flow diagram for the Monte Carlo simulation of photon propagation is shown in the Fig.2. The Photon is initialized with a weight of unity. The distance of the photon's step to the first interaction event is found and the photon is moved. If the photon has left the tissue, the possibility of internal reflectance is checked. If the photon is internally reflected, then the photon position is adjusted accordingly and the program continues, otherwise the photon escapes and the event is recorded as observable reflectance (or transmittance). With each step, the photon's weight is decremented. The photon that indicates photon energy is absorbed by the tissue. The remaining photon weight is then scattered, statistically to achieve a new direction, and a new step is calculated. If the photon weight falls below a threshold minimum value, then Roulette is played either to extinguish the photon or to continue propagations of the photon. Each layer is of homogeneous having refractive index as

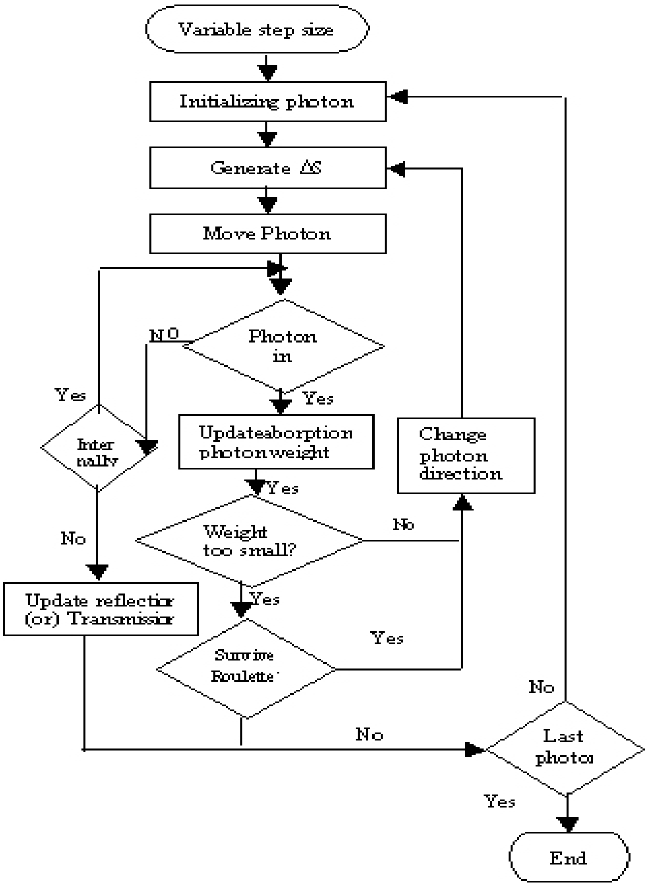


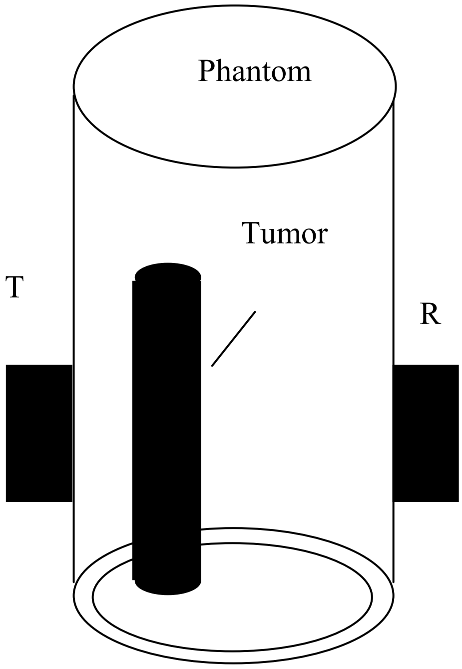
Fig.2. Flow Diagram of a processing model

and dermis respectively. The three dimensional model has been simulated by considering cubical voxels where a group of tissues with same optical properties. The boundary condition 'd' of the medium was checked using the program as shown during simulation.. This program was implemented using C [28], [29], [30]. These same simulation process are applied by considering a skin lesion model of various thickness (2-4mm) and for various wavelength such as 670 nm and 820 nm.

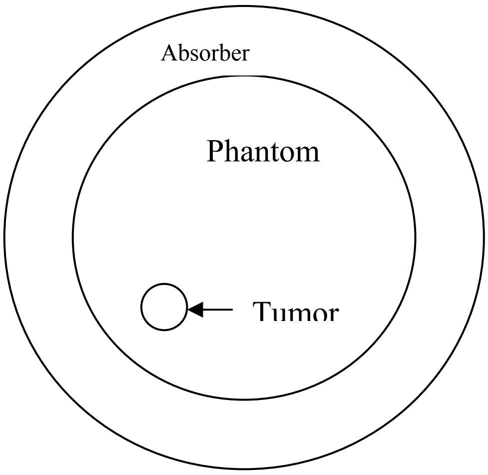
4 Results

To test the validity of the angular and dinstance compensation in practice a collimated laser beam ,first aimed at a spot right on the detector was normally moved from one position to another,in steps 0.2mm.The simulation results are obtained for each and every photon for a given input.. The data acquisition has been carried out with the help of grid pattern, which completely covers the entire surface obtained. Then the simulation result is compared with that of the practical data obtained from laser reflectometry technique to verify the accuracy of the system. In this Monte Carlo simulation of photon scattering, with and without abnormal tissue placed at various locations are compared. From the simulation result, correlation coefficient between nervous thickness and diffuse reflectance has been found out. Various size of skin lesions and with various diameter ring light source are correlated and results are obtained. The correlation analysis between these two gives the suitable wavelengths for the imaging techniques. We have obtained various optical properties such as reflectance, absorption and transmission for different inputs with refractive index (n), absorption coefficient (mua), scattering coefficient (mus), anisotropy (g), size of a layer (d) and number of incident photons for both normal and abnormal tissues.

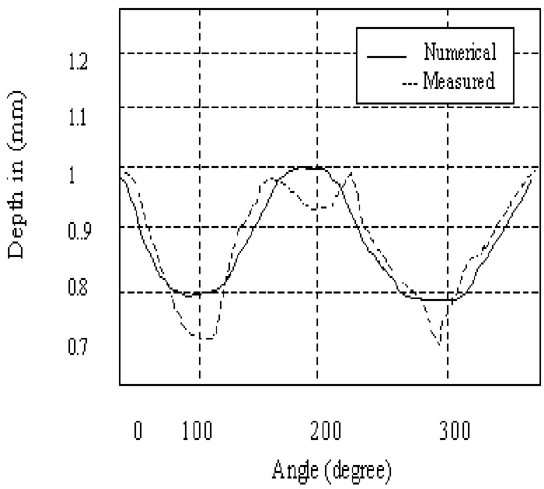
Then the accuracy of the system is verified by comparing the simulation result with that of the practical data obtained from laser reflectometry technique. In these Monte Carlo simulation of photon scattering, with and without abnormal tissue are placed at various locations and the results are compared. Various size of skin lesions and with various diameter ring light source are correlated and results are obtained. show the geometry and cross section of a prototype system. The transmitting and receiving data are obtained using 820 nm laser diode. The circular cylindrical fluid container (diameter D=20 cm). The correlation analysis between these two gives the suitable wave lengths for the imaging techniques. Finally we have compared the simulation with measured data in the laboratory. Fig. 3(a) and (b) surrounded by a wax phantom.



3. (a)



3 (b)



3. (c)

Fig.3 Comparison between measured and simulated result for a rotating phantom and tumor.(a)Geometry.(b).CrossSection. (c). Measured and simulated result at 820nm.

Fig 3(c) shows the comparison of the depth and simulation while the transmitter and receiver are opposite to each other while the phantom and tumor rotate in cycle. The data is normalized with respect to the case where no tumor is present.

The anatomical details of the human forearm and thumb, its equivalent phantom models are analysed. The colour combinations in the outer and inner layers, due to structural constituents of the thumb vary. These are achieved by mixing colours in different proportions.

This method is very flexible and yields an accurate approximation to reality. Laser irradiation of skin using homogeneous and layered geometries has been effectively simulated using MC method. By this procedure the optical parameters of phantoms,which are the same as that of tissues,are determined.

Photons interact with matter via scattering and absorption events. Laser irradiation of skin using homogeneous and layered geometries has been effectively simulated using MC method as shown in Table 1.

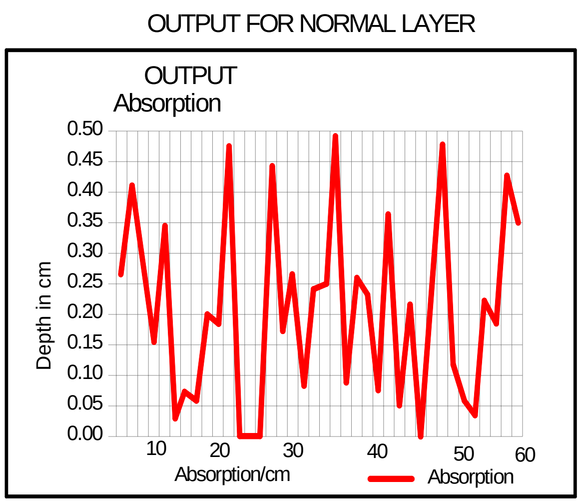
Table 1. Different Values Obtained From Simulation

No.of photons:10000.0

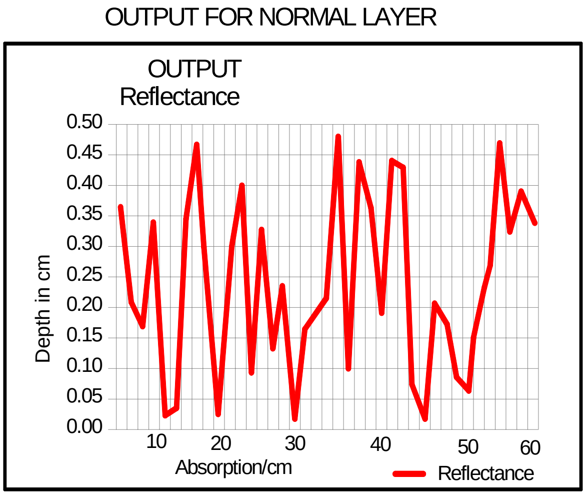
Bin size=1.5 cm

r[cm]	Fsph[1/cm2]	Fcyl[1/cm2]	Fpla[1/cm2]
0.5	0.19954	0.23034	0.7909
1.5	0.01823	0.11979	0.1193
2.5	0.01115	0.10395	0.0493
3.5	3.56105	0.00127	0.0115

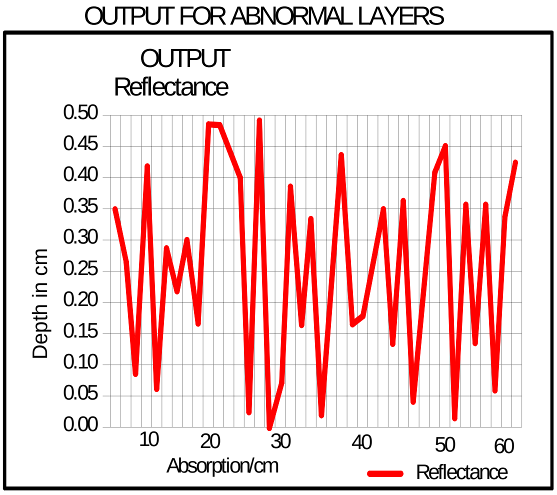
shows the results obtained from java simulation program .Using this technique, we have developed a simulation software for enhancing the fast and accuracy of the system.The simplified model of the simulation viewer are shown in Fig.6. Using this ,user can be able to identify the status of the various optical parameters and also the level of tissue simulation during the light propagation. Fig.4 (a),(b), (c) show that the out put of normal layers which are obtained from simulation. The same manner the Fig.5.(a),(b),(c) shows the output of the abnormal layers.



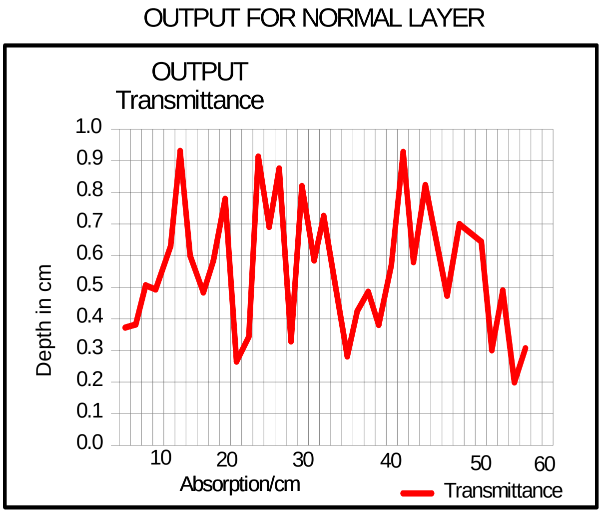
4(a)



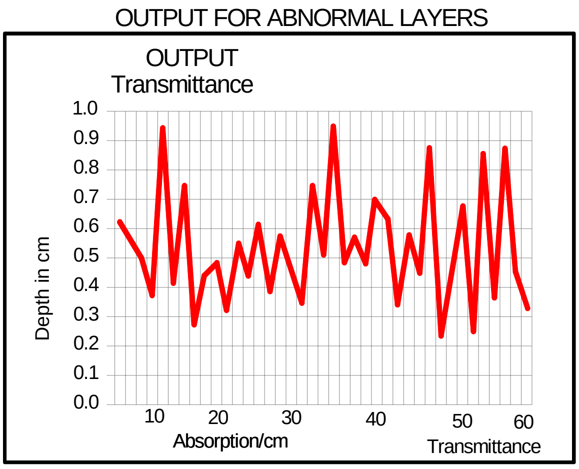
4 (b)



5(b)



4 (c)



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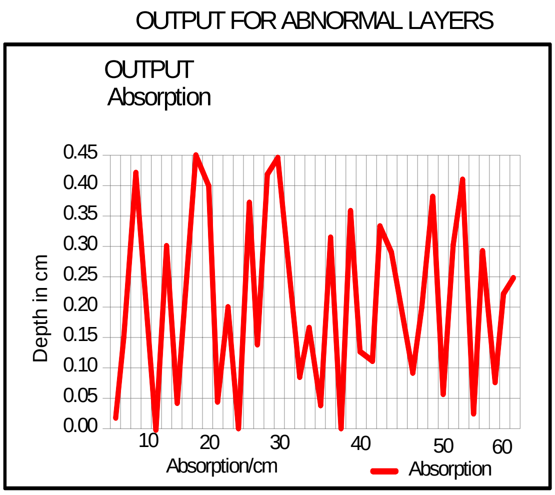

5 (a)

Fig.4. (a) output of normal layers (absorption) (b) output of normal layers(reflectance) (c) output of normal layers(tramsmittance).
Fig.. (a) output of abnormal layers (absorption) (b) output of abnormal layers(reflectance) (c) output of abnormal layers(tramsmittance).

The various input optical parameters such as photon count 10,absorption coefficient 1.0/cm,scattering coefficient 0.0,anisotropy coefficient 0.9 and number of layers 3.We have two approaches for analyzing the effect of an absorbing inclusion with different absorption coefficient on the detection of diffuse photons 1.Run a Monte Carlo simulation for each absorption coefficient 2.Utilize the history file of detected photons achievements the pathlength each detected photon spent in each piece-wise constant region. To begin with , the initial position and direction of the photon is defined. In our case, we consider a point source of photons with a defined direction, entering the medium on the surface. The source can be diverging, as defined by the source numerical aperture (NA), in which case the azimuthal angle is determined by a random number uniformly distributed from 0 to 2π and the elevation (angle from the source axis) is determined from another random number distributed uniformly from 0 to $\sin^{-1}$ (Numerical Aperture).

5 Discussion

The measurement of absorption ,scattering and anisotropy indicate that scattering occurs frequently in the tissueDetermination of the optical parameters is an integral part of the tissue characterization. The parameters involved are scattering,absorption coefficients and anisotropy parameter. These can be determined by matching the spatial variation of tissue or phantom reflectance with that as obtained by the Monte Carlo simulation. By transmission measurement and applying the simulation procedure, the optical parameters of the tissues or phantoms could further be determined. The correlation coefficient analysis gives the specific wavelengths for the multi spectral images. The phantoms prepared by this procedure may effectively be utilized for evaluation and calibration of new optical diagnostic imaging techniques.The software system is implemented in C programming language to locate the abnormality in the tissue and it has a user-friendly interface facilitating interactions relevant to the imaging. Then the accuracy of the system is verified by comparing the theoretical and practical data from the developed software. The wounded region (abnormal) in the different layers of the organ is identified and detected by using the laser reflectometry technique.
The distribution of photons along the depth is within the tissue medium. After the entry of beam in the tissue, this is broadened due to multiple interactions while propagating through the medium. Thus, we omit the boundary calculations at each and every voxel interface along the migration path.Accelerating method improves the simulation efficiency using the photon. Only two checkpoints are used before the photon-tissue interaction, regardless of the number of voxels crossed by the photon. The photons absorbed at various depths of the tissue have been computed. From these data, by an interpolation process a regular pattern (grid points), which completely covers the entire surface has been obtained. For calculation of photons at any grid location, the points surrounding the grid points have been considered and interpolated by above procedure. The points that were already at the grid points, without any interpolation of these have been carried out.To understand the accuracy of the estimates for μs and μa from the diffuse reflectance data , we first made measurement of tissue phantoms with known optical transport parameters. The scattering coefficients of the tissues phantoms that corresponds to various concentrations have been calculated from Monte Carlo Simulation. The refractive index of tissue has been taken to be 1.4 and assumed to be constant in the entire spectral wavelength.

This procedures have been repeated for the wavelength region at 820nm. The present study shows the backscattering from the biological tissues depend on their composition and blood flow. The incidence light on the phantom is in the form of thin sheath of light but the transmitted component is received after a fixed separation. Because of this, the contribution due to scattering at the detector is increased. To average variation in output signals, the transmitted data by each photodiode is collected for a duration of 25 μs and is averaged over 50 samples. The present method for preparation tissue equivalent phantoms is a novel one as this is based on criterion of an exact replica of tissue reflectance profile. The distinct variations in composition, which depends on their functional aspects, is a contributory factor to their colour, which is significantly different from that of skin color. The optical properties of this are determined by matching experimentally measured profile with that of stimulated ones by MC method. The photon scattering under anisotropic conditions provides a good description of photon interaction with various tissues. The reconstructed images of spatial variation of the backscattered intensity or depth variation of photons provide valuable data on the type, size and locations of frost bite in the tissue[32],[33]. In this paper, we consider locations and sizes of anomalies as the core information to search for and focus our attention on the fast and accurate estimation of them. MC Simulation is a statistical technique for simulating random processes and has been applied to light tissue interactions under wide variety of simulations. By this procedure the optical parameters of phantoms, the findings are the same as that of determined tissues. Photons interact with matter via scattering and absorption events. Laser irradiation of skin using homogeneous and layered geometries has been effectively simulated using MC method.

6 Conclusion

Determination of the optical parameters is an integral part of the tissue characterization[31]. The parameters involved are scattering and absorption coefficients and anisotropy parameter. These would be determined by matching the spatial variation of tissue or phantom reflectance with that as obtained by the Monte Carlo simulation. By transmission measurement and applying the simulation procedure, the optical parameters of the tissues or phantoms could further be determined. The correlation coefficient analysis gives the specific wavelengths for the multi spectral images. The phantoms prepared by this procedure may effectively be utilized for evaluation and calibration of new optical diagnostic imaging techniques.The accuracy of the system will be studied with the help of artificial Neural Netwotk (ANN)in the near future.

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