Application of LABVIEW in Measurement of the Biological Tissue's Optical Properties

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Detection of interactions between light and tissue can be used to characterize the optical properties of the tissue. The purpose of this paper is to establish a system that determines the scattering coefficient and absorption coefficient of tissues from two different optical transmission spectrum measured with a miniature fiber optic spectrometer and virtual instrument LABVIEW. In this paper, we combine LABVIEW and spectrometer as a new system to describe the spectrum and analyze the data in real time to realize the measurement of the biological tissue's optical properties, and afford a prerequisite for the other measurement techniques.

Key words: LABVIEW, spectrometer, optical properties.

Tissues can be characterized by their optical properties, which are the absorption coefficient μ_a, the scattering coefficient μ_s, the anisotropy value g and the reduced scattering coefficient $\mu_s' = \mu_s(1-g)$ (Johns, M, *et al*.,2002). Numerous studies about the optical properties of the biological tissue have been interested in the methods of obtaining optical coefficients by measuring the diffuse reflectance with the use of a fiber-optic detector in contact with the tissue surface at varying distances from the source or by using a CCD camera video reflectometer(Zhang, *et al*.,2010). These methods all belong to non-invasive study. While the CCD video camera technology is able to obtain the light intensity distribution of tissue surface with a single wavelength light source and the fiber optic spectrometer technology can get the tissue surface reflectance spectral data at the full range of the light source, both technology need samples with known optical property for training or validation(Zhu,*et al*.,2008). In theory, the optical properties of the simulation samples can be calculated, but in fact, the errors are unacceptable due to the difference of the period of storage and transportation of the simulation sampe. So there's necessary to measure the sample's optical property in real-time and accurately. Generally, the raw solution's optical properties measured by transmission method and insertion method which belong to invasive methods can be used as a standard for other methods(Qin, *et al*.,2006). Therefore, it is very meaningful to establish a system that can determine the scattering coefficient and absorption coefficient accurately and in real-time. The type of the miniature fiber optic spectrometer we used in this paper is USB4000-VIS-NIR made by OCEAN OPTICS CO. The spectrometer is powerful and the response wavelength is 370 to 985nm, but it has its limitation. The measured data can be recognized by its own software only, and the signal to noise ratio of the data is low, data processing and the analysis function can not match the experimenter's demand and can not be carried out in real-time. Moreover

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the data we get from the onboard software has it' own format that can be opened or call by it's own software only. For these reasons, we choose Virtual Instrument LABVIEW which based on G-graphical programming language as the computer software to measure and analyze the spectral data. This software not only have it's own data processing function, but also can call other software's processing function such as Matlab's function. This can realize the request of data processing in real-time.

EXPERIMENTAL

Absorption and scattering coefficient measured by transmission experiment

The measurements of absorption and scattering coefficient by transmission experiment is based on Beer-Lambert law[(Dimofte , et al.,2005):

$$E_c = E_w \exp[-(\mu_a + \mu_s)cd] \qquad \text{...(1)}$$

$$\ln E_c = \ln E_w - cd(\mu_a + \mu_s) \qquad \text{...(2)}$$

Where E_c is the intensity of transmitted light, E_w is the intensity of incident light, c is the concentration of the solution, d is the solution thickness, μ_a is absorption coefficient, μ_s is scattering coefficient. As for the high absorption and low scattering material, namely $\mu_a \gg \mu_s$, μ_a is the approximate value of $\mu_a + \mu_s$. Similarly, for the high scattering and low absorption material, μ_s is the approximate value of $\mu_a + \mu_s$. The experiment process in this paper is as follows, the samples we prepared were placed in a rectangular container and fixed it, then the light normally transmitted through the container. On the other side of the container, the transmitted light was collected into the optical fiber spectrometer. The data of the spectrum got from the optical fiber spectrometer was transmitted to PC by the USB data line. Then the data will be analyzed and the graphics will be displayed by the PC software designed by LABVIEW. The diagram of transmission experiment is shown in fig.1.

Simulation Samples

The simulation samples we used were diluted solutions of Intralipid-20%(Hu, et al.,1991).

The Intralipid-20% used in the experiments is 250ml Intralipid-20% solution produced by KeLunPharmacy Ltd Co., whose ingredients include: 50g refined bean oil, 3g refined lecithin per 250ml Intralipid-20% solution. It has similar optical properties with biological tissue and satisfy the condition . We used the Intralipid-20% as the scattering material in our simulation samples. In this paper, the Intralipid-20% concentrations of the simulation samples we made were 0.99%, 0.90%, 0.83%, 0.76%, 0.71%, 0.66%, 0.62%, 0.55%, 0.50%, 0.45%, 0.41%, 0.36%, 0.30%, 0.25%, 0.20% and 0.15%. The inner diameter of the container namely
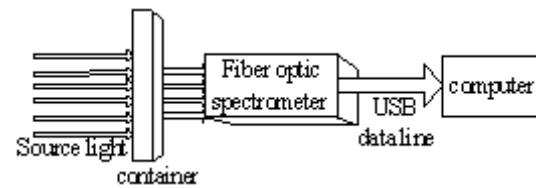

Fig. 1. Diagram of transmission experiment

the solution sample's thickness is 0.5cm

Virtual Instrument Design And Data Processing Display of the spectral data

There are two basic approaches to realize the USB4000 optical fiber spectrometer data shown in LABVIEW. The first one is to make the use of the OmniDriver software and JAVA platform to call the dynamic link library. The disadvantage of this approach is that it is a high cost to build OmniDriver platform. So this method has not been used popularity. The second one is to design PC software about data receiving and processing based on the data transmission format of USB4000 fiber spectrometer's UART or USB communication interface(TAN, et al., 2008 XU, et al., 2004). The disadvantages of the second approach are higher request of electronic and software theoretical basis and a long development cycle.

In order to overcome the disadvantages of the methods mentioned above and achieve the purposes of real-time display and processing , we used LABVIEW software as the basis to design our system. It is because that the LABVIEW's design theory is " software is hardware ", as well as it's graphical programming and high software compatibility, we can not only reduce the hardware cost and development cycle of developers, but also effectively meet the requirements. The fiber

optic spectrometer data can be stored as a TXT document format. Through the LABVIEW's widget " read from spreadsheet file ", the TXT document can be read into a two-dimensional array format, then the two-dimensional array can be split into two one-dimensional arrays, respectively, the input icon display of the X axis and Y axis. The LABVIEW block diagram was shown in Figure3. Transmission spectra data of two different concentrations of biological tissue simulation samples displayed by
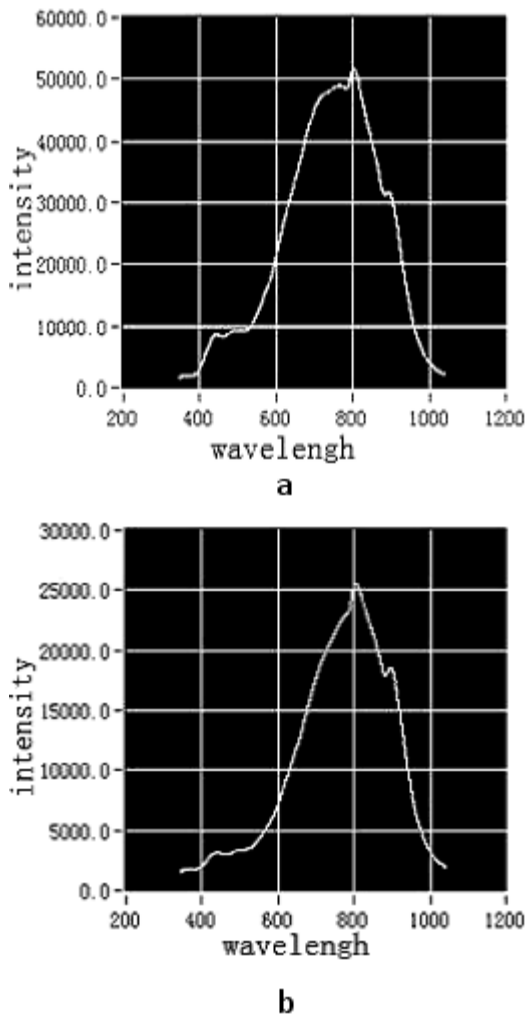

Fig. 2. The spectrum in LABVIEW of two different concentrations(0.30% (a)and0.71%(b))

LABVIEW were shown in figure2
Spectral data processing

The LABVIEW platform can be used to analyse spectral data and design some program according to the formula and data processing function we needed. The transmission spectral intensity difference curve (E1-E2) of two different concentration samples has been shown in figure 4(a). And the curve in figure 4(b) is the difference in natural logarithm ($\ln E1 - \ln E2$). From the formula(1b) with the condition $\mu_s \gg \mu_a$, the formula(2a) was got

$$\ln E_c = \ln E_w - cd\,\mu_s \qquad ...(2a)$$

the relationship between absorption coefficient0 scattering coefficient and the light intensity is shown as

$$\mu_s = (\ln E_{c1} - \ln E_{c2})/(c_2 - c_1)d \quad ...(2b)$$

If $c_2\,0\,c_1$ and d were known, it is easy to

obtain μ_s (Amelink *et al*,2004; QIAN *et al*.,2004).

Figure4(c) is a curve of scattering coefficient versus wavelength obtained from two transmission light intensity of different concentrations.

The advantage of this method is that it can greatly shorten the time of the measurement of the scattering coefficient and realize the measurement in real-time (only two groups of samples's transmission light intensity with known concentrations are needed, then the scattering coefficient versus wavelengh curve can be displayed). In order to verify the method's accuracy, we measured 18 groups of Intralipid-20% solution's with concentrations of 0.99%, 0.90%, 0.83%, 0.76%, 0.71%, 0.66%, 0.62%, 0.55%, 0.50%, 0.45%, 0.41%, 0.36%, 0.30%, 0.25%, 0.20% and 0.15%. Then we used the measured data to make a linear fitting(via LABVIEW calls matlab program with (2a)) at four different wavelength point to obtain the scattering coefficients. The obtained scattering coefficients were used as gold standard in this paper. The fitting curve were shown in Figure 5 (the slope is proportional to the scattering coefficient's of the solution). The negative of the slope calculated at different wavelengths (namely the scattering coefficient values) were shown in Table 1.

DISCUSSIONS

In order to verify the accuracy of our method, we display the curves of the two methods in one figure, so that it can be intuitive to see the

Table 1. The negative of the slope calculated at four different wavelengthsscattering coefficient values at four different wavelengths

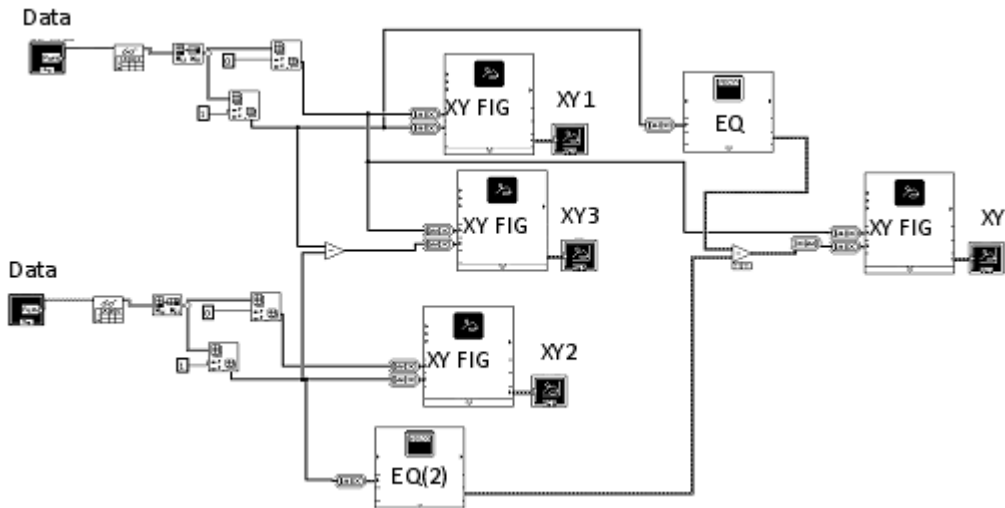| λ(nm)	551	600.13	632.77	627.1
μ_s (mm^{-1})	44.6110	48.9997	49.4427	47.5574

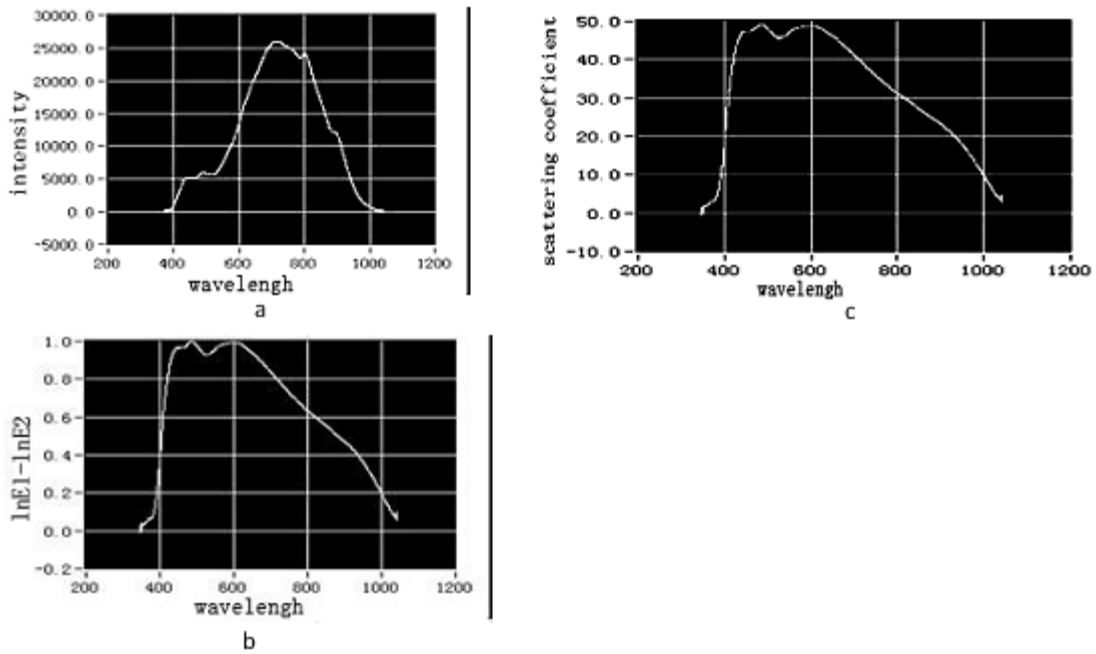**Fig. 3**. The LABVIEW block diagram of data read and display

Fig. 4 a.transmission spectral intensity difference (E1-E2) of two different concentration samples; b. difference values of two transmission light intensity in natural logarithm; c: scattering coefficient versus wavelength curve obtained from two transmission light intensity of different concentrations
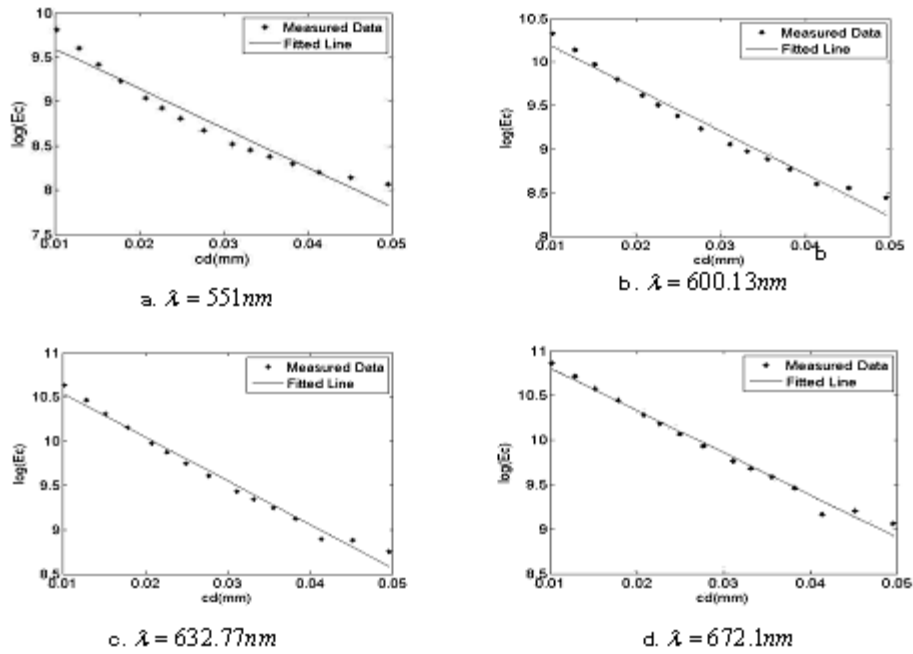
a. $\lambda = 551nm$

b. $\lambda = 600.13nm$

c. $\lambda = 632.77nm$

d. $\lambda = 672.1nm$

Fig. 5. The result of linear fitting at four different wavelengths
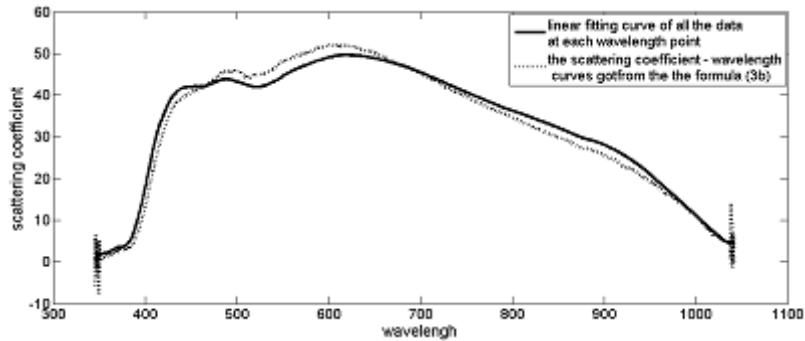

Fig. 6. The result of linear fitting of all the data with formula(2a) at each wavelength points and the scattering coefficient - wavelength curves got from the the formula (2b)

error of two kinds of method. The solid curve shown in Figure 6 was the result of linear fitting of all the data with formula (2a) at each wavelength points(900)(via LABVIEW calls matlab program). The dashed curves are the scattering coefficient versus wavelength gotten from the the formula (2b) with **Figure 6** the result of linear fitting of all the data with formula(2a) at each wavelength points and the scattering coefficient - wavelength curves got from the the formula (2b) two groups of transmission light inetensity of different concentrations. It can be seen from figure 6 that

the difference between the results of linear fitting and calculated from the formula (2b) in wavelength of 400 - 1000nm is acceptable. So our simple measuring method is effective.

In this paper, we combine the Virtual Instrumen(LABVIEW) and the USB4000 fiber optic spectrometer as a new system to describe the spectrum and analyze the data in real time to realize the measurement of the biological tissue's optical properties. In our system we can analyze the data with the LABVIEW program and the other program such as matlab function. Through the comparison

of different methods , our system has been proved to be a effective and high reliability software platform to measure the optical parameters and can afford a prerequisite for the other measurement techniques.

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