Polarization Dependent Characteristics of Skeletal Muscle Tissues

Chia-Wei Sun
Department of Electrical Engineering and Graduate Institute of Electro-Optical Engineering, National Taiwan University, Taipei, Taiwan, R.O.C.
Chih-Yu Wang
Department of Bioengineering, I-Shou University, Kaohsiung, Taiwan, R.O.C.
C. C. Yang and Yean-Woei Kiang
Department of Electrical Engineering, Graduate Institute of Electro-Optical Engineering, and Graduate Institute of Communication Engineering, National Taiwan University,
1, Roosevelt Road, Sec. 4, Taipei, Taiwan, R.O.C.
(phone) 886-2-23657624 (fax) 886-2-23652637 (E-mail) ccy@cc.ee.ntu.edu.tw
Chii-Wann Lin
Graduate Institute of Bioengineering, National Taiwan University, Taipei, Taiwan, R.O.C.

Abstract

Polarization dependent time-resolved intensity profiles of transmitted photons through chicken breast tissues were used for calibrating the anisotropic optical properties of skeletal muscle tissues based on a phenomenological coupling model.

I. Introduction

Recently, there has been an increasing interest in the polarization-gating method for optical imaging. This method is based on the depolarization effect in random scattering of tissues. However, in some tissues such as skeletal muscle tissues, besides the de-polarization effect due to random scattering, coherent coupling between the two mutually perpendicular polarization components may occur [1,2]. Such coherent coupling is due to certain anisotropic optical properties of the tissue structures. In this paper, we report the optical characterization results of chicken breast tissues based on a phenomenological model.

II. Experiment Procedures

An Argon laser pumped mode-locked Ti:sapphire laser was used to provide around 100 fsec laser pulses at 800 nm (Fig. 1). Two polarizers were used for polarization gating. The optical signals were directed to a streak camera with a fiber bundle.

III. Phenomenological Model

The time-gated, polarization dependent optical signals can be described with the coupled differential equations

$$\begin{cases} \dfrac{\partial I_x}{\partial z} = -\mu_x I_x + \kappa_{xy} I_y \\ \dfrac{\partial I_y}{\partial z} = -\mu_y I_y + \kappa_{yx} I_x \end{cases} \quad (1)$$

Here, μ_x and μ_y are the extinction coefficients for polarization components in the x and y directions, respectively, and κ_{xy} and κ_{yx} are the coupling coefficients of polarization from the y to x and the x to y directions, respectively. The x direction was designed to be along the chicken breast tissue filaments. Optical signals propagate in the z direction. The coupled equations in (1) were solved with initial and final conditions given by our experimental data.

IV. Experimental and Calibrated Results

The time-resolved intensity profiles of three input polarization cases are shown in Fig. 2. In each case, curves I_{pi} and I_{ci} represent the co-polarized and the cross-polarized output components. Cases 1, 2, and 3 (i =1, 2, 3) describe the results of 0, 45, and 90 degrees input polarization, respectively. The chicken breast tissue sample has the thickness varying from 1.3 to

1.5 cm. A thin chicken bone with thickness of around 2 mm was stuck into the thick portion of the tissue sample.

In Table 1, we show the calibration results of those coefficients in (1). The cases of S1through S5 represent the different data sets used for calibration. The thickness' of the tissue samples for S1 through S5 are 1.5cm, 1.5cm, 1.4cm, 1.3cm, and 1.5cm, respectively. The case S5 refers to the data from a location of chicken bone. The ranges in this table were obtained by reasonably adjusting a calibration factor of the streak camera. Usually, μ_x is larger than μ_y. This indicates that in such tissues, polarization parallel to tissue filaments is more strongly extinguished than that perpendicular to tissue filaments. The coefficient κ_{yx} is larger than κ_{xy}, indicating that polarization in the x direction is more easily coupled to the y direction than the other way. From Table 1, we can see the results from different data sets are quite consistent no matter the variation of tissue thickness. With the chicken bone stuck in the soft tissue, all the coefficients are increased, implying that scattering is enhanced.

V. Conclusion

In conclusion, based on time-gated and polarization-dependent transmitted intensity measurements, we have calibrated a set of extinction and cross-polarized coupling coefficients for describing optical signal transmission through chicken breast tissues. Such calibration was implemented based on a phenomenological mode.

Acknowledgement:

This research was supported by National Health Research Institute, The Republic of China, under the grant of NHRI-GT-EX89.

References:

1. G. Yao, and L. V. Wang, Opt. Express 7, 198(2000).
2. V. Sankaran, J. T. Walsh, Jr., and D. J. Maitland, Opt. Lett. **25**, 239 (2000).

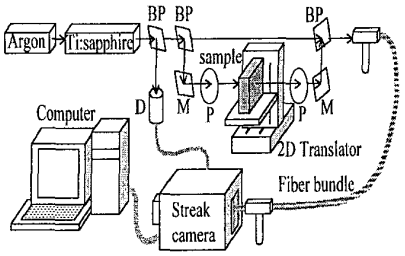

Fig. 1 Experimental setup.

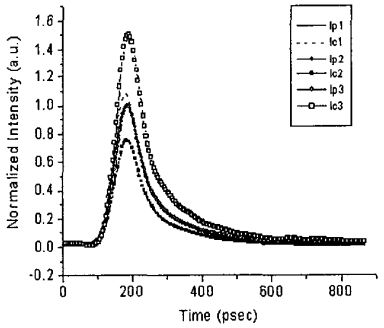

Fig. 2 Normalized and synchronized intensity profiles of the three cases.

Table 1 Five sets of extinction and coupling coefficients (unit: cm^{-1}).

	S1	S2	S3	S4	S5
μ_x	2.41-3.39	3.11-3.79	2.96-3.45	2.26-2.93	2.87-3.88
μ_y	1.43-2.5	1.92-2.53	1.46-2.13	1.37-1.89	2.32-3.3
κ_{xy}	0.49-0.51	0.78-0.8	0.95-1.01	0.65-0.67	0.76-0.82
κ_{yx}	1.61-1.69	2.79-2.82	2.57-2.72	1.69-1.86	2.14-2.27