www.apbp2009.org

The 4th ASIAN AND PACIFIC RIM SYMPOSIUM ON BIOPHOTONICS

Date	:	27-29, May 2009
Location	:	Shilla Hotel, Jeju island, Korea
Organized by	:	Optical Society of Korea / Biomedical Optics Division
Sponsored by	:	Korea Optical Industry Association Advanced Photonics Research Institute, GIST Graduate-program of Medical System Engineering(GMSE), GIST Chungbuk BIT Research-Oriented University Consortium Intelligent System Research Division, KIST SeongKeong Photonics HANA engineering Co., Ltd. Huentek Co., Ltd. Fovice Co. Ainnotech Inc.

International Commission for Optics
Commission Internationale d' Optique

OSK
Optical Society of Korea

EOS European Optical Society Coherence for Europe

SPIE

The American Optics Society

OSA

osj

OWLS

cos

16:15-16:30	**SPE-07** Differences in bypass blood flow during EC-IC bypass between Moyamoya disease and non-Moyamoya ischemic stroke evaluated by optical techniques, Y. Murata et. al. (Nihon University School of Medicine, Japan)		
16:30-16:45	**SPE-08** Spectral measurement of fast optical signal of neural activity and its theoretical origin, Jonghwan Lee et. al. (Seoul National University, Korea)	**DEV-04** Development of a position and time sensitive ion detector for stigmatic imaging mass spectrometry, Hisanao Hazama et. al. (Osaka University, Japan)	**NAN-07** Near-infrared laser stimulation of live neuronal networks cultured on MEMS based planar microelectrode arrays, Yoonkey Nam et. al. (KAIST, Korea)
16:45-17:00	**SPE-09** SERS imaging of specific cancer markers overexpressed in single cells using antibody-conjugated metal nanoprobes, Sangyeop Lee et. al. (Hanyang University, Korea)	**DEV-05** Novel wavelength-swept FDML laser source using broadband Raman amplifier, Eun Joo Jung et. al. (Pusan National University, Korea)	**NAN-08** Photonic detection of neurotransmitters by Raman spectroscopy, Young-Jae Oh et. al. (KAIST, Korea)
17:00-19:00	**Poster presentation (with finger snack & drink)**		

FRIDAY, May 29

	Room Lotus 1	Room Lotus 2	Room Lotus 3
	Biomedical Diagnostics Using Optical Microscopy(II) Session Chair : Prof. David D. Sampson	**Optical Fiber Devices for Bioscience(II)** Session Chair : Prof. Min Yong Jeon & Dr. Daniel Day	**Laser Tissue and Cells Interaction(I)** Session Chair : Prof. Ho Lee
09:00-09:30	**MIC-03 [Invited]** Multifocal multiphoton microscopy based on multianode photomultiplier tubes, Ki Hean Kim (POSTECH, Korea)	**DEV-06 [Invited]** *In vivo* single-cell detection with optical fiber based nanobiosensor, Chang Ming Li et. al. (Nanyang Technology University, Singapore)	**PDT-01 [09:00-09:25] [Invited]** The advent of laser therapies: a review of technologies, recent trends and future directions, Kin Chan (Fourier Biotechnologies, USA)
09:30-10:00	**MIC-04 [Invited]** Three dimensional optical microscope using stereoscopy and integral imaging, Nam Kim et. al. (Chungbuk National University, Korea)	**DEV-07 [Invited]** Fabrication of multi-wavelength light sources for biomedical optical imaging technologies, Young-Geun Han (Hanyang University, Korea)	**PDT-02 [09:25-09:45] [Invited]** *In vivo* targeted gene transfer based on photomechanical waves, Shunichi Sato et. al. (National Defense Medical College, Japan) **PDT-03 [09:45-10:05] [Invited]** Endoscopic diagnosis and selective treatments using a mid-infrared tunable pulsed laser, Kunio Awazu et. al. (Osaka University, Japan)
10:00-10:15	**MIC-05** Focusing of light: effects of apodization and polarization, Colin J. R. Sheppard (National University of Singapore, Singapore)	**DEV-08** Fabrication of double clad fiber coupler for biomedical imaging system, Seon Young Ryu et. al. (GIST, Korea)	**PDT-04 [10:05-10:20]** The thermal response of biological tissue, Kyunghan Kim et. al. (Korea Institute of Machinery and Materials, Korea)
10:15-10:30	**MIC-06** Single molecular orientation measurement by polarization filtering, Mamoru Hashimoto (Osaka University, Japan)	**DEV-09** Multipoint illuminating experiments on human melanocyte cell and fibroblast cell, Chung-Jen Ou et. al. (Hsiuping Institute of Technology, Taiwan)	**PDT-05 [10:20-10:35]** Photodynamic bacterial inactivation for wounds and photosensitizer dose imaging by photoacoustic wave, Akihiro Hirao et. al. (Keio University, Japan)
10:30-10:45	**Coffee Break**		
	Biomedical Diagnostics Using Optical Microscopy(III) Session Chair : Prof. Seung Hee Han	**Optical Devices and Systems for Nano-Bio(III)** Session Chair : Prof. Chang-Seok Kim & Prof. Chang Ming Li	**Laser Tissue and Cells Interaction(II)** Session Chair : Dr. Kin Chan
10:45-11:15	**MIC-07 [Invited]** Measurement of various metal nanowires using near-field scanning phase interferometer, Sang-Youp Yim (GIST, Korea)	**DEV-10 [Invited]** Femtosecond biophotonics for fabrication, manipulation and imaging, Daniel Day et. al. (Swinburne University of Technology, Australia)	**PDT-06 [10:45-11:10] [Invited]** Gold nanoshell mediated vascular-focused hyperthermia enhances the efficacy of radiation therapy, Parmeswaran Diagaradjane et. al. (MD Anderson Cancer Center, USA)
11:15-11:30	**MIC-08** Sensitivity assessment of simulated Raman scattering microscopy, Fumihiro Dake (Osaka University, Japan)	**DEV-11** Focusing of surface plasmons In hollow metal disk for cascaded enhanced surface-enhanced Raman scattering, Haixi Zhang et. al. (The Chinese University of Hong Kong, China)	**PDT-07 [11:10-11:35] [Invited]** Ultrashort laser machining for biomolecule manipulation, Hae Woon Choi et. al. (Keimyung University, Korea)
11:30-11:45	**MIC-09** Surface plasmon coupled emission microscopy, Wai Teng Tang (National University of Singapore, Singapore)	**DEV-12** Microring sensor based on surface plasmon resonance of attenuated reflection mirror, Doo Gun Kim et. al. (KOPTI, Korea)	**PDT-08 [11:35-11:50]** Comparative investigation of the effects of traditional acupuncture and laser acupuncture on the treatment of induced focal ischemia and hypertension in rats, C. S. Na et. al. (Dongshin University, Korea)
11:45-12:00	**MIC-10** Detection of magnetic nanoparticles by magnetically mediated self-assembly of superparamagnetic microbeads for biosensing, Yoshitaka Morimoto (Tokyo Institute of Technology, Japan)	**DEV-13** The control of mesenchymal stem cell using a fluorescent polymer, Jungmok You et. al. (Yonsei University, Korea)	**PDT-09 [11:50-12:05]** Gene transfer into spinal cord by pulsed laser-induced stress wave, Takahiro Ando et. al. (Keio University, Japan)
12:00-12:15	**MIC-11** Construction of confocal laser scanning microscopy based on Galvano mirror scanning system, EungJang Lee (Yonsei University, Korea)	**DEV-14** Magnetically labeled immunoassay based on magneto-optical transmittance of solutions containing self-assembled chains of functionalized magnetic nanoparticles, Sang Yoon Park et. al. (Tokyo Institute of Technology, Japan)	**PDT-10 [12:05-12:20]** Development of less-invasive laser angioplasty for atherosclerosis using nanosecond pulsed laser at 5.75 μm, Katsunori Ishii et. al. (Osaka University, Japan)

Spectral Measurement of Fast Optical Signal of Neural Activity and its Theoretical Origin

Jonghwan Lee[1], Sung June Kim[1,2]
[1]Interdisciplinary Program in Neuroscience, Seoul National University, Korea
[2]School of Electrical Engineering and Computer Science, Seoul National University, Korea

Abstract: This study demonstrates the optical measurement of neural activity in brain tissues using custom-built high-speed confocal near-infrared spectrophotometry. In addition, the origin of the optical signals is theoretically discussed based on our novel neuron model.

1. Introduction

Functional imaging technologies of human brain activity have played an essential role in recent advances of brain science and neural engineering. To date, there have been a couple of techniques to record neural activity in the brain. For example, implanted electrodes, electroencephalography (EEG), functional magnetic resonance imaging (fMRI) were utilized for such purpose. However, they have been limited in clinical uses by their own drawbacks. The fMRI, one of the most widely used method, shows the time delay of several seconds due to the neurovascular coupling [1]. For these reasons, there has been a growing need for a new optical technique of noninvasive, fast and intrinsic brain activity imaging.

As a fundamental study for the development of such technique, this study demonstrates the detection of fast optical signals of neural activity in brain tissues. We monitored a change in the near-infrared (NIR) transmission and reflection spectra of the brain tissue during neural activation. Additionally, a transient cellular volume change (tCVC) was proposed as one of the dominant origins of the fast optical responses.

2. Experiment Methods

2.1 Instrumentation

Since the neural activity in the brain tissue has short time constant (~ ms), the NIR spectra should be recorded at a high sampling rate of 1000 full spectrum lines per second. So we built our high-speed confocal NIR spectrophotometry based on the optical design in Figure 1. The spectral region from 800 to 1300 nm was monitored using 256-element InGaAs detector arrays. The measurement volume within the brain tissue was adjusted by using the confocal pinhole.

2.2 Materials

Rat cortical slices were used in this study as the brain tissue sample. Transverse slices of 400-um thickness were obtained from four week old male Sprague Dawley rats through the conventional methods [2]. As shown in Figure 2, the stimulating electrode was placed in the cortical layer IV and the recording electrode (0.3-1 MΩ in impedance) was placed in the layer II. The light beam was focused on the position in the layer III where the evoked neural activity would propagated through. Pole-alternating monophasic voltage stimulations of 150 μs in duration and 3-30 V in amplitude were applied at a random frequency around 1 Hz.

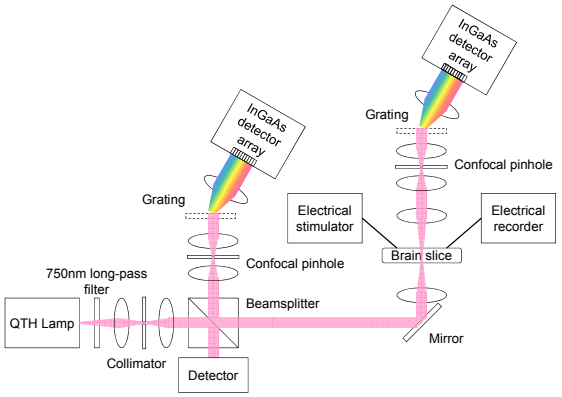

Fig.1. Schematic design of the custom-built high-speed confocal NIR spectrophotometry.

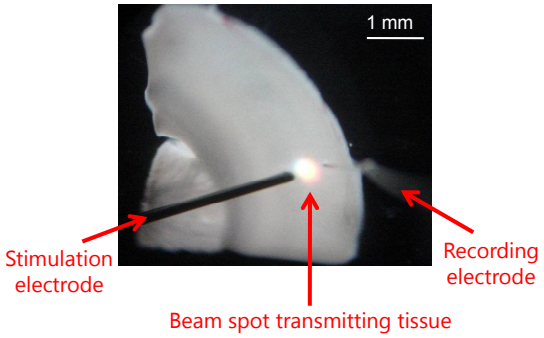

Fig.2. Alignment of the stimulation electrode, beam spot and recording electrode on the neural connection in the rat cortical slice.

3. Experiment Results

As a control, we first recorded the electrical and optical signals while not aligning the electrodes and beam spot on the neural connection. Figure 3(A) illustrates that only the stimulus artifact was observed in the electrical recordings. No significant optical change was observed.

When we evoked proper neural activity by aligning the electrodes on the neural connection, the population spike and excitatory post-synaptic potential (EPSP) were observed in the electrical recording. Simultaneously, both of the transmittance

and reflectance of the tissue increased at the onset of the EPSP, and slowly relaxed. Similar optical changes were observed across preparations. Although the magnitude and wavelength dependency of the change were slightly different among preparations, every optical signal showed monophasic change and slow relaxation compared to the electrical signals.

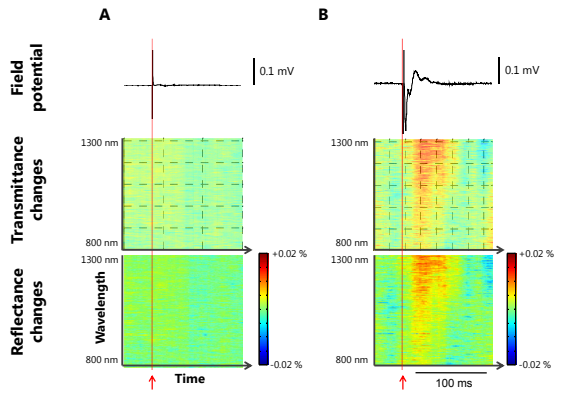

Fig.3. Electrical and optical recordings in the two cases: (A) not aligned on the neural connection as a control, and (B) aligned on the neural connection in the brain slice with suprathreshold stimulations. The gray lines at the top show the electrical signals. Two-dimensional plots are the relative changes in the NIR transmission and reflection spectra, in which the vertical axis represents the wavelength and the horizontal axis represents time. The red arrows in the bottom indicate the moment of stimulation. The electrical and optical recordings were averaged for one hundred trials.

4. Theoretical Study

According to our measurement, the optical change showed its temporal dynamics different from the electrical signal. It implies that the optical change would be originated from, rather than the membrane potential itself, some other neurophysiological event accompanying neural activity. We hypothesized that the tCVC would show the time course similar to the measured optical response and hence could be one of the origins.

4.1 Neuron Model

Since the conventional Hodgkin-Huxley model cannot provide how the cell volume changes during neural activation, we established novel neuron model for quantitative tCVC calculation. This model introduced new variables of the cell volume, intracellular concentrations and water flux through the membrane. We made mathematical connections between those variables by using Nernst-Plank equation, continuity equation and Fick's 1st law.

As shown in Figure 4, the numerical solution of our model for a simplified spherical single cell showed that the cell volume would change during neural activation. Remarkably, the time course of the tCVC was very similar to the measured optical signals (monophasic change and slow relaxation compared to the membrane potential). This result supports that the optical signal with such different time courses might be originated from the microanatomical change of the tissue produced by the tCVC during neural activation.

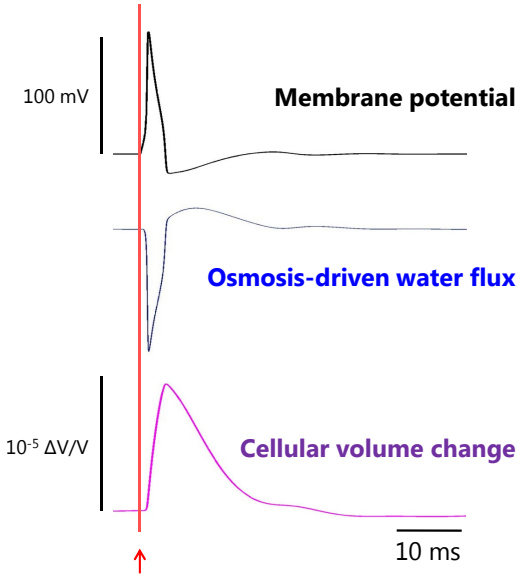

Fig.4. Numerically computed tCVC based on our neuron model.

4.2 FDTD Simulation

Our next question was how the tCVC could cause a change in the transmittance and reflectance of the tissue. We conducted the finite-difference time-domain computation for this question. As the result, both of the forward and backward scattering from the single cell increase as the cell size increase, which well agrees with the measured results.

5. Conclusions

We monitored the NIR transmission and reflection spectra of the brain tissue during neural activation, and found fast optical changes associated with the local field potentials. As the origin of the optical responses, the tCVC was proposed and investigated with our neuron model and FDTD computation.

6. References

[1] C. T. Moonen *et al.*, Science **250**, 53 (1990).
[2] Z. A. Bortolotto *et al.*, Current Protocols in Neuroscience, Unit. 6.13.1-6.13.23 (2001).

7. Acknowledgments

This study is supported by three research grants: the Nano-Bioelectronics and Systems Research Center of Seoul National University (R11-2000-075-01001-1); the Air Force Office of Scientific Research, USAF, United States of America (FA4869-07-1-4072; and a grant (M103KV010024-08K2201-02410) from the Brain Research Center of the 21st Century Frontier Research Program, Korea.