# Scientific Report of MSc Zofia Lorenc

Short Term Scientific Mission (STSM) to noninvasive optical methods detecting disordered blood flow patterns at the

University of Oulu (Finland)

2017-01-16 to 2017-03-17

**STSM application number:** COST-STSM-BM1205-34885

**STSM grantee:** Zofia Lorenc MSc

**STSM period:** 2017-01-16 to 2017-03-17

**Home institution & country:** Warsaw University of Technology, Warsaw (Poland)

**Host institution & country:** University of Oulu, Oulu (Finland)

**Objective of the collaboration:** Noninvasive optical methods detecting disordered blood flow patterns

**Description of the work carried out during the STSM and main results**:

The goal of this multidisciplinary research is to provide new biophotonics based tools and more comprehensive methods for detecting disordered blood flow patterns. For this purpose, the Optoelectronics and Measurement Techniques unit (OPEM) in University of Oulu, builds functional multimodal imaging equipment for different optical tissue imaging purposes. The equipment can be used with a broad range of spectrum and data analysis methods are developed for in vitro as well as in vivo use.

To enable observing changes in blood or liquid flows and their spectral information, a multilayered optical phantom with tubes mimicking vessels was developed. My main part of the work during the STSM was to build this multipurpose test setup and perform preliminary test measurements with it. Test measurements were performed using an near infrared spectroscopy (NIRS) device, developed in OPEM [4]. In the test measurements, four wavelengths 660 nm, 830 nm and 980 nm were used.

Phantom, consisting of four tissue-mimicking layers (skin, skull, grey and white matter) were fabricated to resemble the optical properties of forehead tissues [1]. Thicknesses of rectangular (9.5 x 9.5 cm) tissue layers were: skin (3 mm), skull (7 mm), grey matter (4 mm) and white matter (10 mm). The phantom was created according to previously established procedures [2]. In short, the PDMS consisting of a base material and a curing agent were mixed together (10 parts of base to 1 part of curing agent) with glycerol in the amounts ranging from 1 to 10 parts, to achieve the scattering coefficient most similar to that of the tissues. The influence of absorbing agent was not studied in this case as we focus solely on the scattering-related optical phenomena [3].

To generate the liquid flow, the Infusion Workstation Orchestra was used. Three syringe pumps and one modulator generated different speed level of liquid. The system is shown in the Figure 1.

Fig. 1. Optical phantom of part of head with system to mimic blood flow in phantom - the Infusion Workstation Orchestra with three syringe pumps and one modulator.

The red colored water (spectrum of used fluid is shown in figure 2 left) mimicking deoxygenated blood was used. Relationship between real body fluids are shown in figure 2 right.

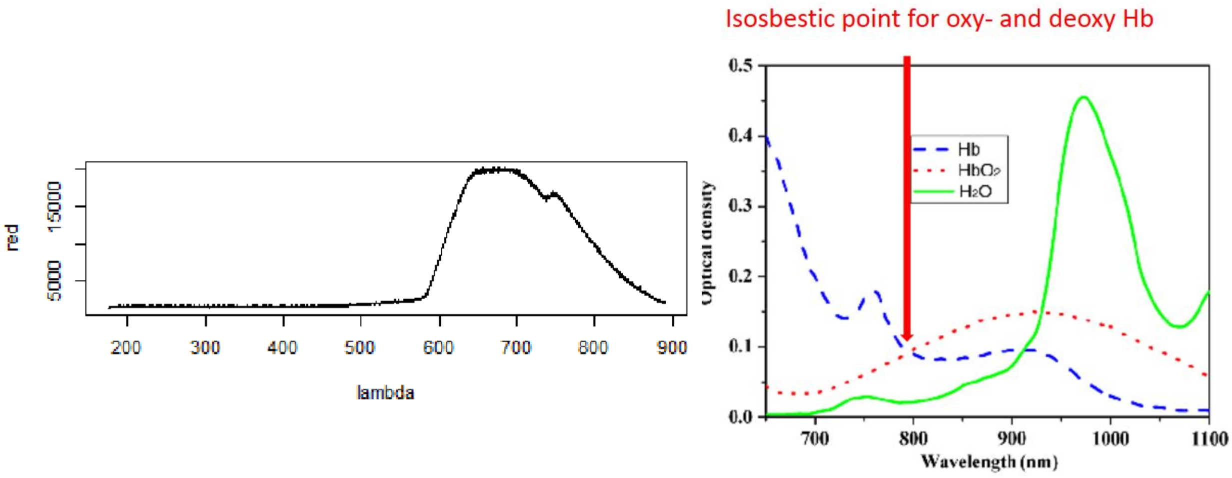


Fig. 2. (left) Spectrum of tested red colored water; (right) Spectrum of deoxygenated blood (blue dashes), oxygenated blood (red points), water (green line), with highlighted isosbestic point for oxy- and deoxy hemoglobin.

During the experiments infusion of the red colored water and clear water was changed by turns. It was obtained by using two syringes - one was with clear water and second with red colored water. The ends of tubes, connected with syringes, were put together to one tube, where liquids were mixed.

## Results

Red colored water and clear water were mixed into the tube during the experiment. The tube was placed between the skull and gray matter layers. Flow of water was constant and the red colored water and clear water was changed by turns.

Four different source-detector distances: 3 cm, 4 cm, 5 cm and 6 cm were used and the optode was attached on the skin layer phantom. The purpose of the test experiment was to study sensitivity of three wavelengths (660 nm, 830 nm and 980 nm) for these liquids changes in CSF mimicking layer when using different source-detector distances.

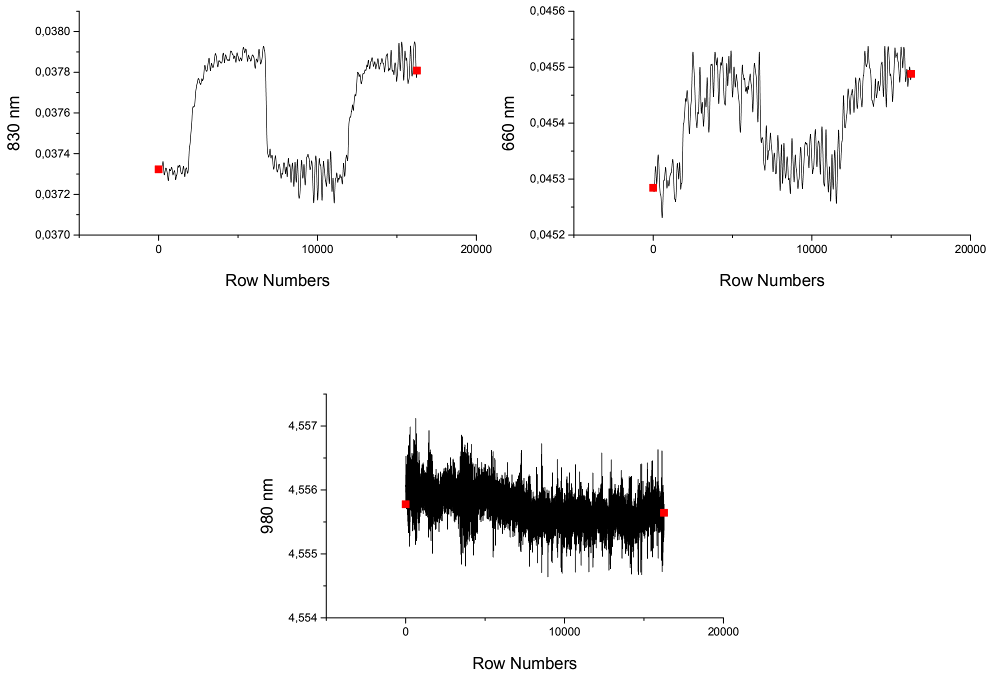


Fig. 3. Measurement using source-detector distance of 3 cm. Upper left plot is for 830 nm, upper right 660 nm and below for 980 nm.

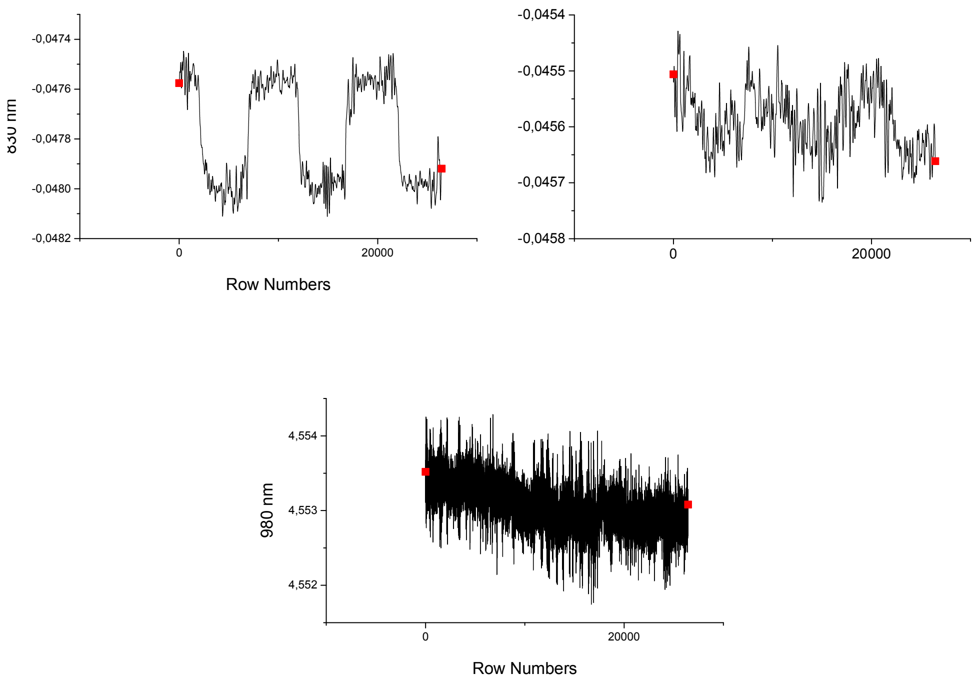


Fig. 4. Measurement using source-detector distance of 4 cm. Upper left plot is for 830 nm, upper right 660 nm and below for 980 nm.

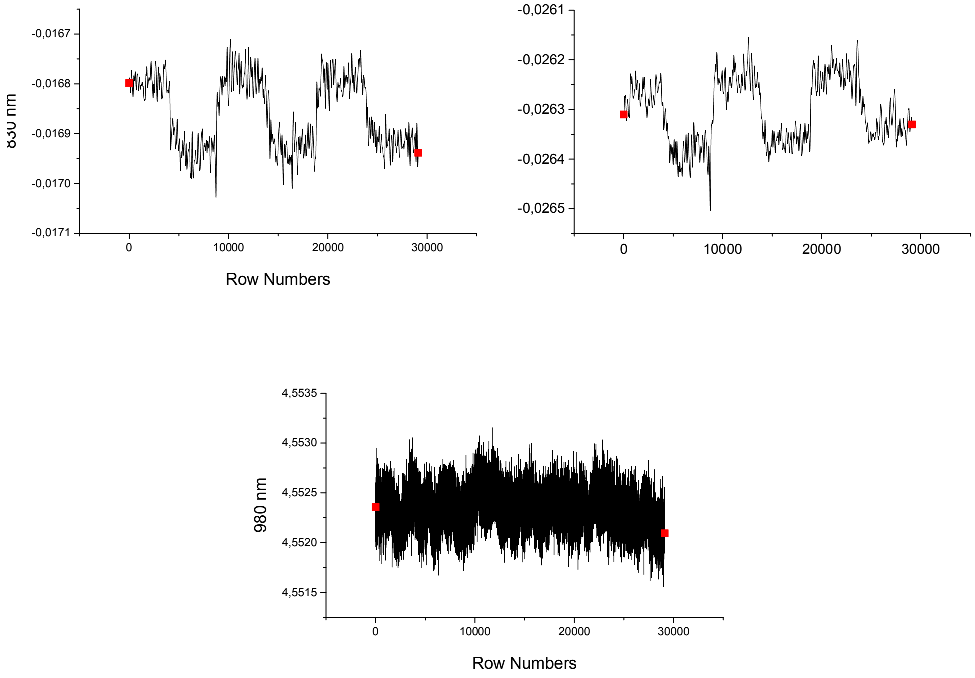


Fig. 5. Measurement using source-detector distance of 5 cm. Upper left plot is for 830 nm, upper right 660 nm and below for 980 nm.

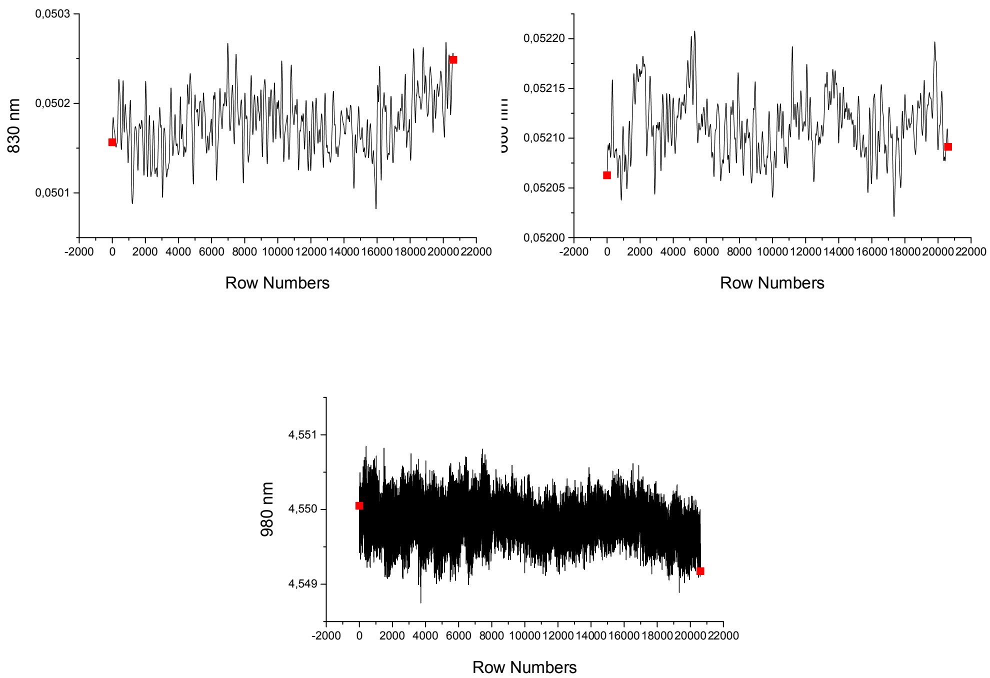


Fig. 6. Measurement using source-detector distance of 6 cm. Upper left plot is for 830 nm, upper right 660 nm and below for 980 nm.

## Discussion

In accordance to the spectrum of red colored water shown in Figure 2 wavelengths of 660 nm and 830 nm are affected by red colored water whereas 980 nm is not. The best quality of signal sensitivity to red colored water was registered at source-detector distances of 3 cm and 4 cm. Wavelength of 830 nm gave the most distinct response.

According to our experiment, the changes between red colored and clear water are not visible at source-detector distance of 6 cm. The reduced sensitivity to the liquid inside the tube may be caused by the longer path length of photons between the source and detector [5]. In this case the tube is inside a much bigger optical measurement volume and seems to have too low SNR to sense the liquids. However, further measurements needs to be carried out. Our next step is to experiment by increasing concentration of red pigment by regularly adding bigger amount of red colored water in the same intervals. Using Beer Lambert law we may calculate relative concentrations of the red pigment in water and compare results with known concentrations/mixed liquids.

Presented test setup provides us a possibility to study and experiment how concentrations of different liquids can be detected optically inside brain mimicking phantoms, and to develop methods to detect disordered blood flow patterns. Further, results gathered with the setup can be then utilized in development of various in vivo applications.

## References

[1] Wróbel, M. S., Popov, A. P., Bykov, A. V., Kinnunen, M., Jędrzejewska-Szczerska, M., Tuchin, V. V., "Multi-layered tissue head phantoms for noninvasive optical diagnostics," J. Innov. Opt. Health Sci. 8(3), 1541005 (2015).

[2] Wróbel, M. S., Popov, A. P., Bykov, A. V., Tuchin, V. V.., Jędrzejewska-Szczerska, M., "Nanoparticle-free tissue-mimicking phantoms with intrinsic scattering," Biomedical Optics Express 7(6), 2088 (2016).

[3] Myllylä T, Vihriälä E, Pedone M, Korhonen V, Surazynski L, Wróbel M, Zienkiewicz A, Hakala J, Sorvoja H, Lauri J, Fabritius T, Jędrzejewska-Szczerska M, Kiviniemi V, Meglinski I (2017) Prototype of an opto-capacitive probe for non-invasive sensing cerebrospinal fluid circulation, Invited Paper, Proc. of SPIE 10063-22.

[4] Myllylä, T., Korhonen, V., Surażyński, Ł., Zienkiewicz, A., Sorvoja, H. and Myllylä, R., (2014) Measurement of cerebral blood flow and metabolism using high power light-emitting diodes. Measurement, 58, pp.387-393.

[5] Korhonen, V.O., Myllyla, T.S., Kirillin, M.Y., Popov, A.P., Bykov, A.V., Gorshkov, A.V., Sergeeva, E.A., Kinnunen, M. and Kiviniemi, V., (2014) Light propagation in NIR spectroscopy of the human brain. IEEE Journal of Selected Topics in Quantum Electronics, 20(2), pp.289-298.

STSM OUTCOME FORM

| STSM application number | Home institution & country | Host institution & country | Objective of the collaboration | Results of the collaboration |
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| COST-STSM-BM1205-34885 | Warsaw University of Technology, Warsaw (Poland) | University of Oulu, Oulu (Finland) | Noninvasive optical methods detecting disordered blood flow patterns | For detecting blood and different liquid flow patterns a test measurements setup including optical multilayered optical phantoms was built.<br><br>Sensitivity of 3 different NIR wavelengths at 4 different source-detector distances to different liquids, when flowing inside the optical phantom, was studied.<br><br>Further experiments and collaboration in this study will be carried out. |

I would like to confirm the successful realization of the described short-term scientific mission (STSM) by PhD student Zofia Lorenc. It was profitable carried out in the conditions here specified. Prospects of potential further collaborations on topics related to noninvasive optical methods used in bioimaging are expected in the near future.

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