Instrument for estimation of red blood cells speed distribution using laser-Doppler spectrum decomposition

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Abstract— **Laser-Doppler instrument optimized for estimation of red blood cells speed distributions in microvascular bed was developed. The instrument allows for decomposition of laser-Doppler spectra which based on an assumption that the spectrum can be represented as a linear combination of Doppler shift probability distributions. The decomposition procedure requires high signal to noise ratio in measured spectra. We developed the laser-Doppler instrument with signal to nose ratio greater than 80dB which allows for measurements of blood speed distributions in microvasculary system in real time. The hardware and software architecture of the instrument and first results of its validation during *in-vivo* experiment with postocclusive reactive hyperaemia test are presented.**

Keywords— **laser-Doppler, blood flow, red blood cell speed distribution, microcirculation**

I. INTRODUCTION

Laser-Doppler flowmetry is a relatively new optical diagnostic technique [1]. Broadening of light spectra caused by Doppler effect during light interactions with red blood cells (RBC) can be observed as fluctuations of AC component of detected light. Tissue microperfusion is proportional to the first moment of AC component of power spectrum density of detected light. However measured signal cannot be calibrated in absolute units [2-4], depth of light penetration is unknown [5-6] and characteristic of the instrument is nonlinear [7]. In this paper we will show new method of signal interpretation and first *in-vivo* results obtained from a laser-Doppler instrument optimized for estimation of red blood cells speed distribution in microvascular system.

Considering limitations of laser-Doppler spectra decomposition method [8-10], we have built the LDI with high signal to noise ratio (SNR) required for successful estimation of speed distribution. This technique is based on assumption that measured laser-Doppler spectrum can be represented as a linear combination of Doppler shift probability distributions which depend only on scattering angle distribution.

In-vivo occlusion test was carried out on healthy volunteers. The speed distributions of RBC during the test in comparison to laser-Doppler perfusion signal (LDP) will be presented.

II. INSTRUMENTATION

Laser-Doppler instrument optimized for estimation of speed distributions of moving particles, e.g. red blood cells, was developed.

Block chart of the instrument is presented in figure 1. Modified laser diode driver iC-WK2D (iC-House, Germany) with high stability was used. Change of laser power during 4 hours is < 1% and noise amplitude is < 0.25%. Photodiode with integrated amplifier OPT101 (Burr-Brown, USA) was applied for photodetection. To avoid power supply distortion battery supply was used. Fully charged battery allows for 40 hours of instrument operation. The system assures high signal to noise ratio (SNR > 80dB). Analog outputs of measured signals are connected with DAQ Card 6062E (National Instruments, USA) using shielded cables and shielded connector SCB-68 (National Instruments, USA). Two optical fibers (diameter 200μm, NA = 0.4) were used for delivery of light to the tissue and for transmission of remitted light to the photodetector. Distance between source and detection fibers mounted in the measurement probe (optode) was equal to the fiber diameter.

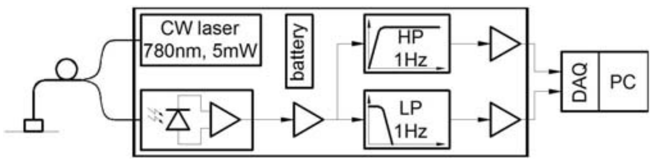

Fig. 1 Bloch chart of laser-Doppler instrument

Measured signals were sampled with frequency of 40kHz and collected in 2048-probe buffers. Average of DC component and 1024 samples of FFT of AC component of signal from photodetector were calculated. Single spectrum was obtained every 51.2ms (19.53Hz). DC values, first moment of the spectrum and spectrum itself were saved for further analysis in ASCII files. Software for signal acquisition was created in LabVIEW environment (National In-

O. Dössel and W.C. Schlegel (Eds.): WC 2009, IFMBE Proceedings 25/VII, pp. 554–555, 2009.
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struments, USA) and the decomposition procedure was implemented in Matlab (MathWorks, USA).

Because the single measured spectrum was to noisy for further decomposition, spectra were averaged in 5.12 s interval (100 spectra) in order to reach high SNR. This sampling frequency suggests that the decomposition procedure can be applied for real time estimation of speed distribution.

III. RESULTS

Developed laser-Doppler instrument was tested during in-vivo measurements on healthy volunteers. To obtain the controlled changes in microperfusion the arterial occlusion test was applied. Measurement probe of the instrument was fixed on middle finger of the volunteer's left hand. Laser-Doppler signal was recorded during rest flow (5.5 min.) occlusion (2 min) and reperfusion period (5.5 min.).

An example of measured LDP and RBCs speed distributions during the occlusion test is shown in figure 2.

The effect of arterial occlusion is clearly visible in blood perfusion and in calculated speed distributions of red blood cells.

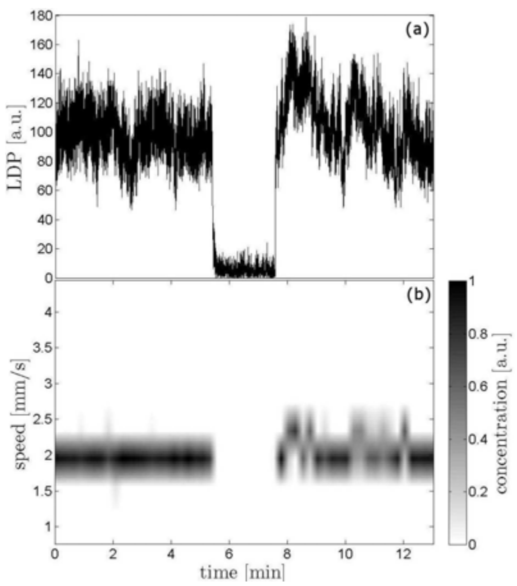

Fig. 2 Perfusion signal (a) and speed distributions (b) of red blood cells during *in-vivo* occlusion test.

IV. CONCLUSIONS

Low noise laser-Doppler instrument with SNR > 80dB was developed. The instrument allows to collect spectra for the decomposition procedure and finally to obtain speed distribution of red blood cells. We showed that the instrument can be implemented in real time measurements of red blood cells speed distributions in human microvascular system. Maxima of speed distributions obtained for rest flow and reperfusion measurements are similar to values measured in capillaries using other methods [11].

ACKNOWLEDGMENT

This study has been supported by the Polish Ministry of Science and Higher Education in frame of research project R1303401.

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