State University – Education-Science-Production Complex
SCIENTIFIC-EDUCATIONAL CENTER BIOMEDICAL ENGINEERING
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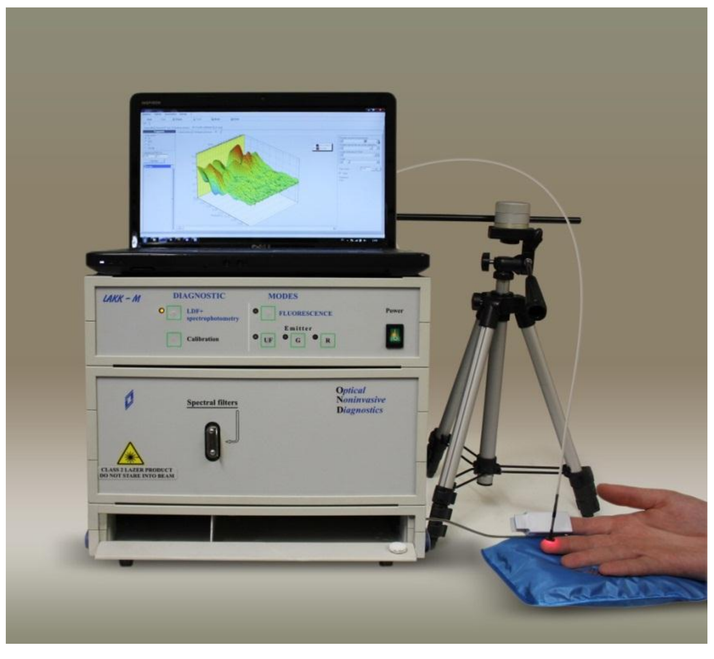
Complex analysis of blood microcirculation, oxygenation and redox status in tissue

Andrey Dunaev, Victor Sidorov

"Medical DIagnostic LASEr system" (MEDILASE, #251531) *2010-2014*

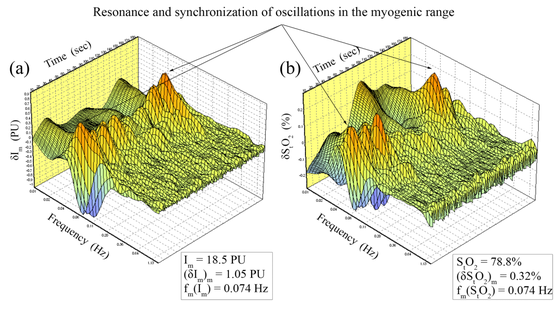
The aims of this IAPP project was to overcome scientific and technical challenges to the realisation and adoption of a unique multifunctional non-invasive laser diagnostic system.

Multifunctional laser diagnostic system "LAKK-M" (SPE "LAZMA" Ltd)



4 channels in one device:

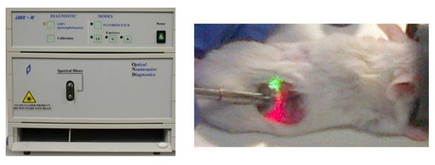
- fluorescence spectroscopy (FS);
- absorption spectroscopy (tissue reflectance oximetry – TRO);
- laser Doppler flowmetry (LDF);
- pulse oximetry.



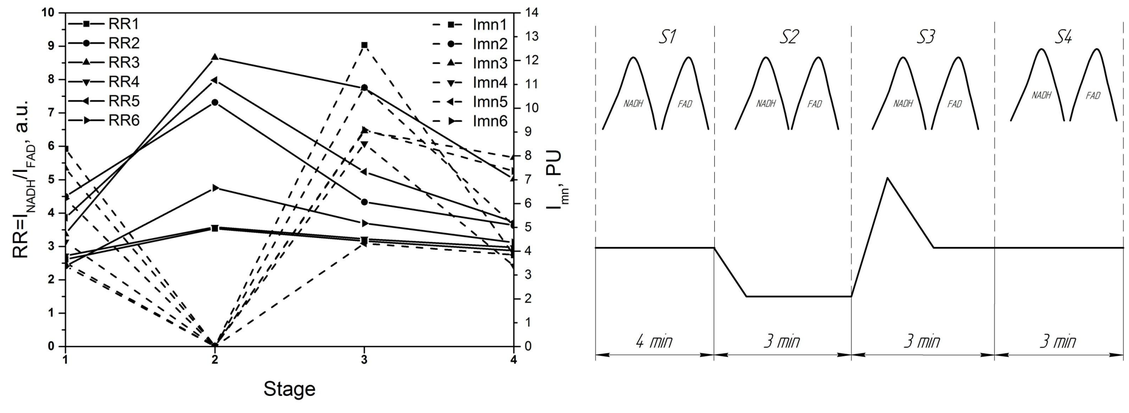
Typical example of the 3D wavelet analysis of synchronized rhythms of microvascular blood flow (a) and oxygen saturation (b) under adaptive changes.

"Advanced Bladder cancer LAser Diagnostics and thErapy" (ABLADE, #324370) *2013-2017*

This IAPP project aims to advance the development of an integrated laser diagnostic and therapeutic technique for use in detecting and treating bladder cancer.



- **The study of fluorescence spectra in mice using "LAKK-M" system**
- **The study of adaptation of microcirculatory-tissue systems based on correlation between nutritive blood flow and redox ratio**

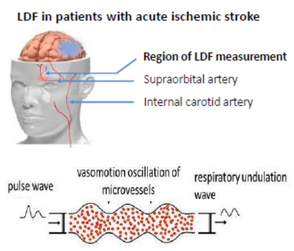


Typical relationship between redox ratio (RR) and nutritive blood flow (Imn) registered on the middle finger of 6 volunteers in an experiment of 4 stages with occlusion test.

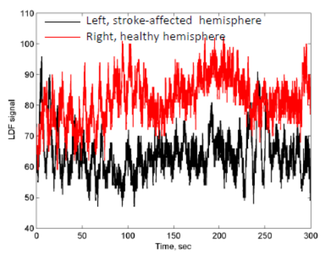
PROSPECTS:

1. Laser diagnostics of cerebral microhaemodynamics

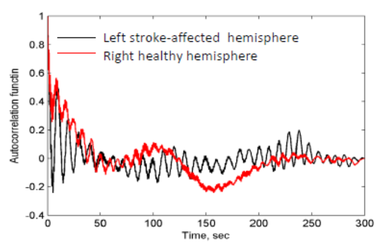
This project proposes an application of LDF method to research of patient haemodynamics at post-acute ischemic stroke (AIS) conditions. These pilot results show that LDF, along with model-based analysis of the LDF signal characteristics can be used as an effective diagnostic method for early detection of adverse cerebral microhaemocirculation to permit necessary corrections.



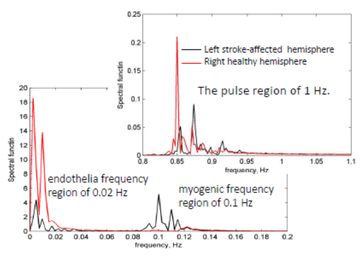
Endothelia, myogenic and neurogenic mechanisms of vasomotion oscillation of microvessels



LDF signals measurement on the right ("healthy") and left (stroke affected), branches of the supraorbital arteries



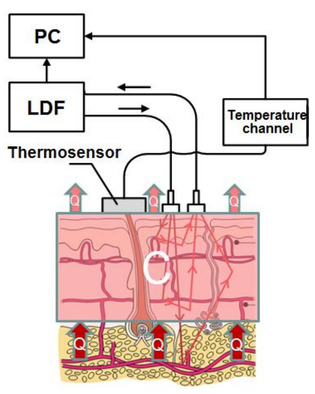
Auto-correlation function of LDF signals from the right , "healthy" (red line) and left, stroke-affected (black line), branches of the supraorbital arteries.

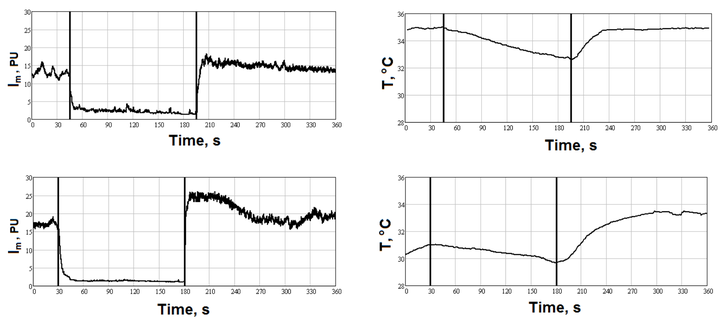


Spectral density of correlation function of LDF signals in the range of endothelial low frequency region of 0.02 Hz, myogenic high frequency region 0.1 Hz, and in the pulse range of 1 Hz.

2. Method and device for diagnostics the functional state of peripheral vessels with vibration disease/Raynaud's phenomenon

The purpose of this research is a data correlation study of LDF and cutaneous thermometry for occlusion test in patients with vibration disease (VD) or Raynaud's phenomenon (RP). Combined thermometry and LDF allow the investigation of changes in thermal parameters of patient's tissue during the progression of the VD/RP.

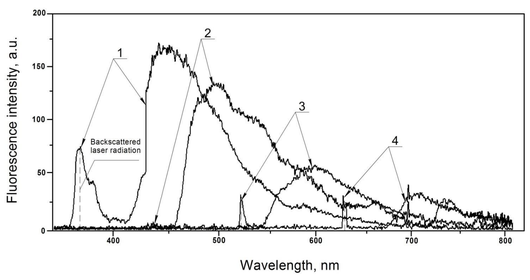




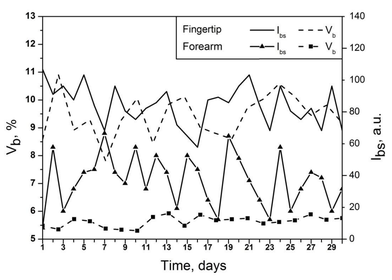
Typical examples for the LDF- and thermograms for conditionally healthy volunteer (a, b) and patient with vibration disease (c, d)

3. Methodological and instrumentation provision of fluorescence spectroscopy for medicine

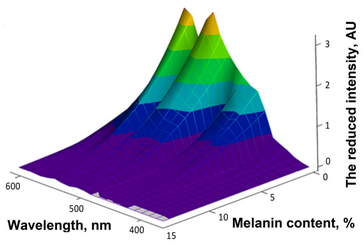
The reliability of FS is affected by multiple factors, including the availability of data concerning the scattering and absorbing properties of specific tissues in specific conditions (for example, the contribution of skin melanin), light pollution at optical fibre tip and instrument errors such as excitation source instability, photodetector limitations, light filter precision, grating precision, CCD performance, etc. To achieve clinically significant and reliable results, issues of accuracy, convergence and measurement variation also need to be addressed.



Fluorescence spectra of endogenous fluorophores in the palmar surface of Caucasian skin type at 365 nm (1), 430 nm (2), 532 nm (3) and 635 nm (4)



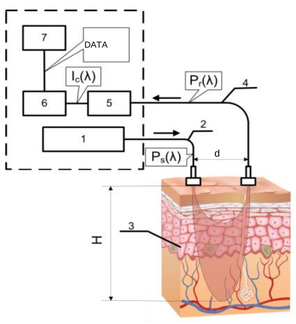
Graphs of parameter changes Ibs and Vb in two zones of the skin for one volunteer



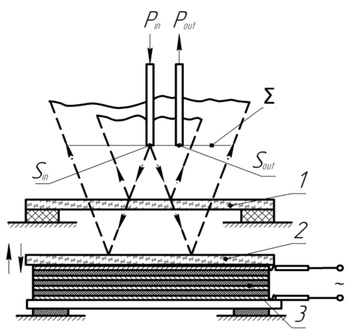
Set of model fluorescence spectra for different content of melanin in the skin

4. Metrological support of devices for laser Doppler flowmetry

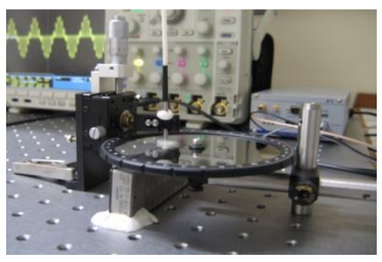
This project proposes a prototype hardware-software system for metrological support of LDF devices. It uses a piezoelectric actuator and Doppler light-diffusing layer to reproduce the desired dimension of the measurable value. This solution is capable of improving the utility of this class of medical devices.



1 – laser (600…1100 nm); 2 – probing fiber; 3 – biotissue; 4 – receiving fiber; 5 – photodiode; 6 – electronic processing scheme; 7 – computing device.



Principles of operation for calibration of LDF devices: 1 – light transparent plane-parallel plate; 2 – moving diffuse reflector; 3 – electromechanical transducer (batch piezoelectric actuator); Sin – aperture of source; Sout – aperture of the receiver; Σ – plane coincidence of aperture of receiver and source



Experimental setups of measure for calibration of LDF devices

Acknowledgements:

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