Combined medical diagnostic system with separated Laser-Doppler and reflectance oximetry channels.

Amzina M.V.[1)], Micheev A.A.[1)], Rogatkin D.A.[1, 2)], Sidorov V.V.[2)]

[1)] Moscow State Institute of Electronics and Mathematics "MSIEM"
B. Trehsvyatitelsky per. 3/12, Moscow, 109028, RF
tel./fax 7-095-917-08-01

[2)] Department of Radiology of Moscow Regional Research & Clinical Institute «MONIKI», Shepkina str., 61/2, Moscow, 129110, RF
tel. 7-095-684-56-23, fax. 7-095-315-12-84,
email: laserrog@mtu-net.ru

ABSTRACT

On the basis of studying of opportunities of Reflectance Tissues Oximetry (RTO) as well as on the basis of RTO and Laser Doppler Flowmetry (LDF) comparative data, received in Moscow Regional Research and Clinical Institute "MONIKI" while patients with the peripheral blood microcirculation disorders were under examination, it was offered to unite the RTO and LDF techniques in a single diagnostic system. The new two-channel diagnostic system will contain the first LDF channel to measure the blood microcirculation parameters and the second RTO channel to register an average peripheral blood oxygenation. In the report the features of the new system design and a number of experimental data on correlation of RTO and LDF results are considered. The prospects of amalgamation of these two different techniques in a single diagnostic device are shown as well.

1. INTRODUCTION

Today the noninvasive (in vivo, in situ) and real-time methods of diagnostics are desirable for a general clinical practice. One of such promising technique is the optical multi-wave noninvasive elastic scattering and absorption spectrophotometry[1-3]. It potentially allows a doctor to measure easy a number of important medical and biological (M&B) parameters, the peripheral blood saturation (SO2) for example, during the different medical procedures directly in the doctor's cabinet. Recently we have reported of our new medical noninvasive spectrophotometric diagnostic apparatus

"Spectrotest"® (Fig.1), which has been created by our cooperation[3,4]. During last years it was being tested in different clinical applications at Moscow Regional Research and Clinical Institute "MONIKI". One of the promising fields of its applications in medicine is the real-time monitoring of the peripheral blood microcirculation and peripheral capillary blood oxygenation (PCBO) processes for patients with different disorders of the peripheral haemodynamics including a number of professional diseases, for example – the "vibrational white fingers" (VWF)[5,6]. The other analogous technique is the Laser Doppler Flowmetry (LDF) realized in apparatus "LAKK-01" (Fig. 2), which allows noninvasive measurements of peripheral blood microcirculation in tissue. The ability of both techniques to register and calculate all M&B diagnostic parameters in a real time mode allows a doctor to apply different functional tests in his medical inspection. In our present research different functional tests were used for the VWF patient examination to study the correlation between LDF and RTO data. On the basis of this study we would like to know the prospects of development of new diagnostic equipment for the medical noninvasive spectrophotometry.

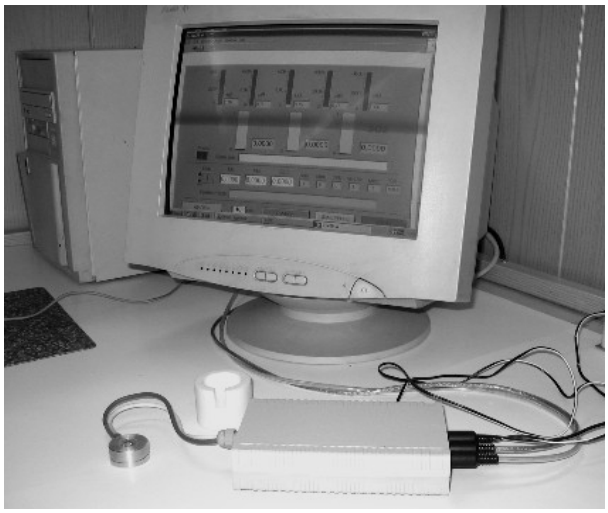

Fig.1. Optical noninvasive reflectance oximeter "SPECTROTEST"

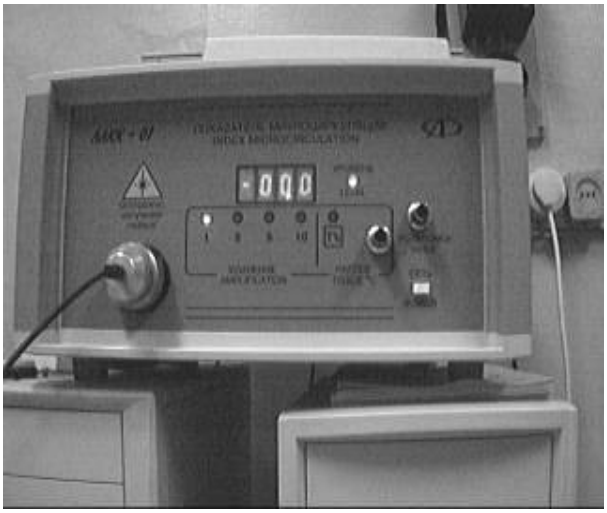

Fig.2. Laser-Doppler Flowmeter "LAKK-01"

2. CLINICAL EXPERIMENTS

In our study 20 patients with VWF and 20 healthy volunteers were under examination. All patients had a first (40%) or second (60%) stage of illness. The average age of them was 42.2 years. Three standard functional tests – the occlusion test (OT), the cooling test (CT) and the respiratory one (RT) – were used to understand better the specialties of the patients' clinical state. The "Spectrotest"® was used to register and indicate a hand's finger PCBO during applied functional tests.

Temporal resolution for the "Spectrotest"® to measure and calculate all average PCBO was around 1 sec. In a parallel mode an index of microcirculation (**Im**) was measured from the other patients' hand finger by the Laser Doppler Flowmeter "LAKK-01" (Fig.3). The parameters of applied functional tests were as follows: the CT consisted in immersing hands in water with temperature 5 – 8 °C on 5 min; the duration time of OT was 6 min and 1-3 min for the standard RT. All parameters were registered during 1 min before each test and 5 min after one. For the CT additionally the duration time was 25-30 min after cooling.

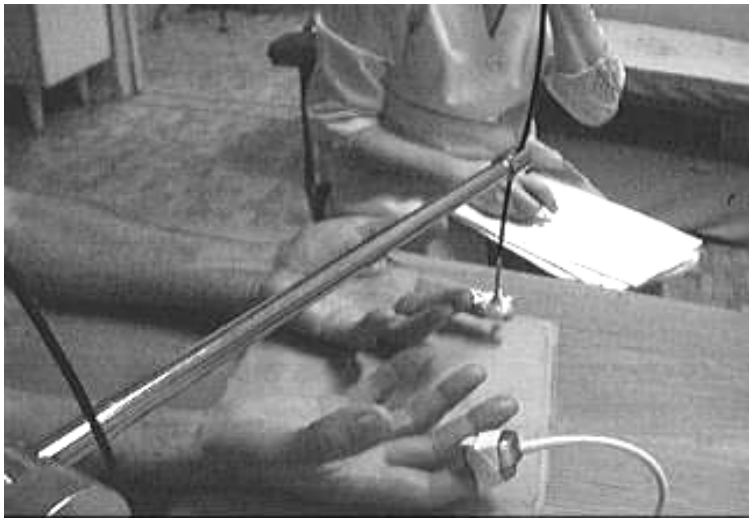

Fig.3. Main setup of clinical experiments.

3. RESULTS AND DISCUSSION

The more visual results are presented in fig.4-6. It is well visible that all results have a good correlation between each other and, moreover, add each other. Under occlusion, for example, RTO technique allows a doctor to observe an SO2 decreasing in a tissue, while the LDF index of microcirculation shows for a doctor nothing except the so-called "*biological zero level*". After occlusion procedure all parameters show the post-occlusion hyperemia in a finger skin. In a common case for the patients with VWF the decreasing of SO2 during OT was more differ than for the healthy volunteers (Fig.4 a, b). As it was estimated the different changes in SO2 and different peripheral blood rhythms can be observed during the RT as well (Fig.5 a, b). After CT we have found out a correlation between all M&B parameters and surface temperature of a finger (Fig. 6).

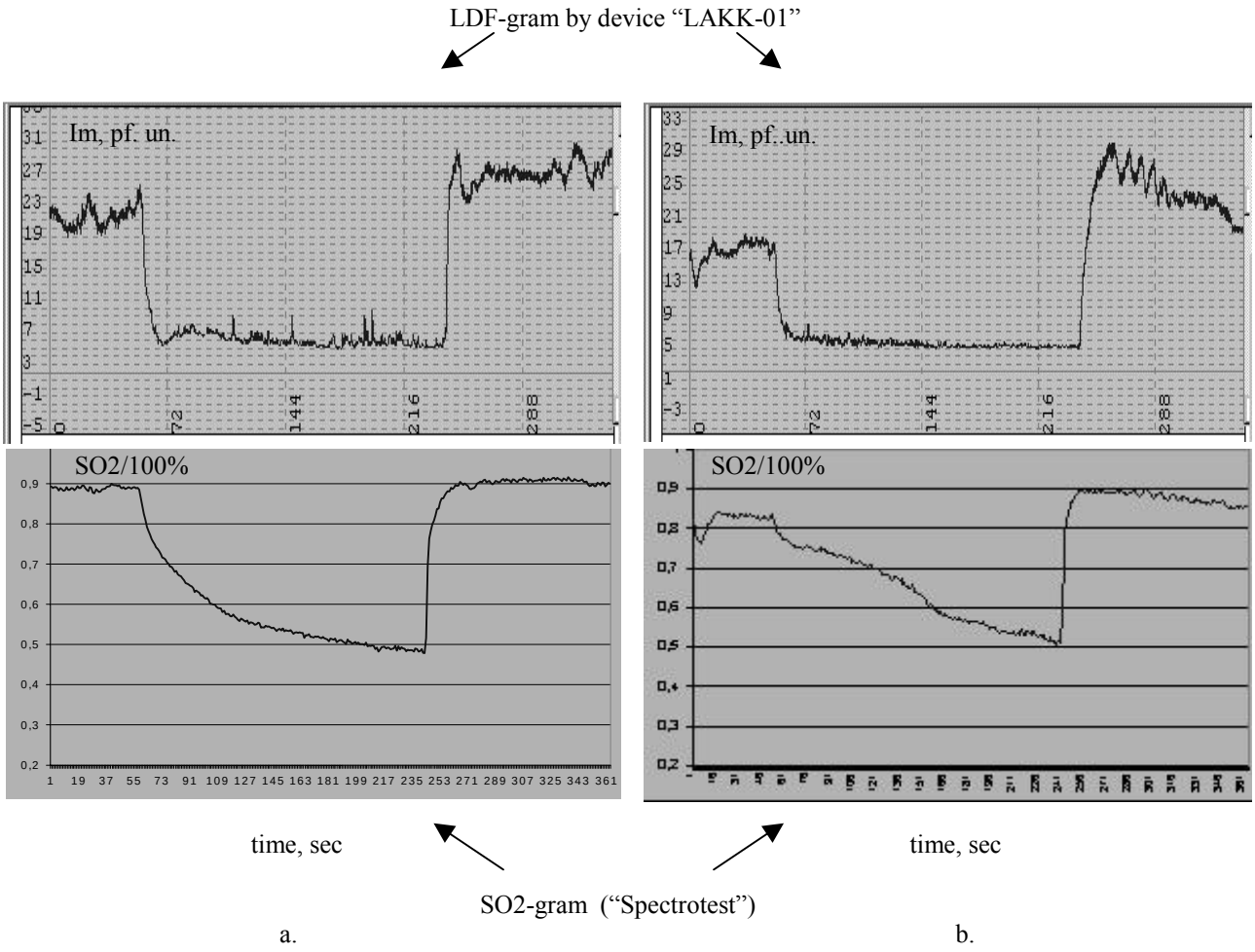

Fig.4. Measured parameters during OT.
a. Normal case; b. Case of vibration disease.

Moreover, in the same time the similar rhythms have been displayed by both LDF and RTO technique (Fig.4-6). From one hand, it shows the good work of our oximeter “Spectrotest” ® and a reality of a calculated SO2 parameter. From the other hand presented results indicated that:

1. The different PCBO rhythms can be detected by the real-time RTO technique like the blood perfusion rhythms by the LDF one;
2. The frequency analysis technique, like the same in LDF, can be applied for the real-time RTO signal to analyze the different frequency spectra in PCBO rhythms;
3. Thus, we can approve that overlapping of both technologies (LDF and RTO) opens new horizons in diagnostics of various diseases of peripheral blood system.

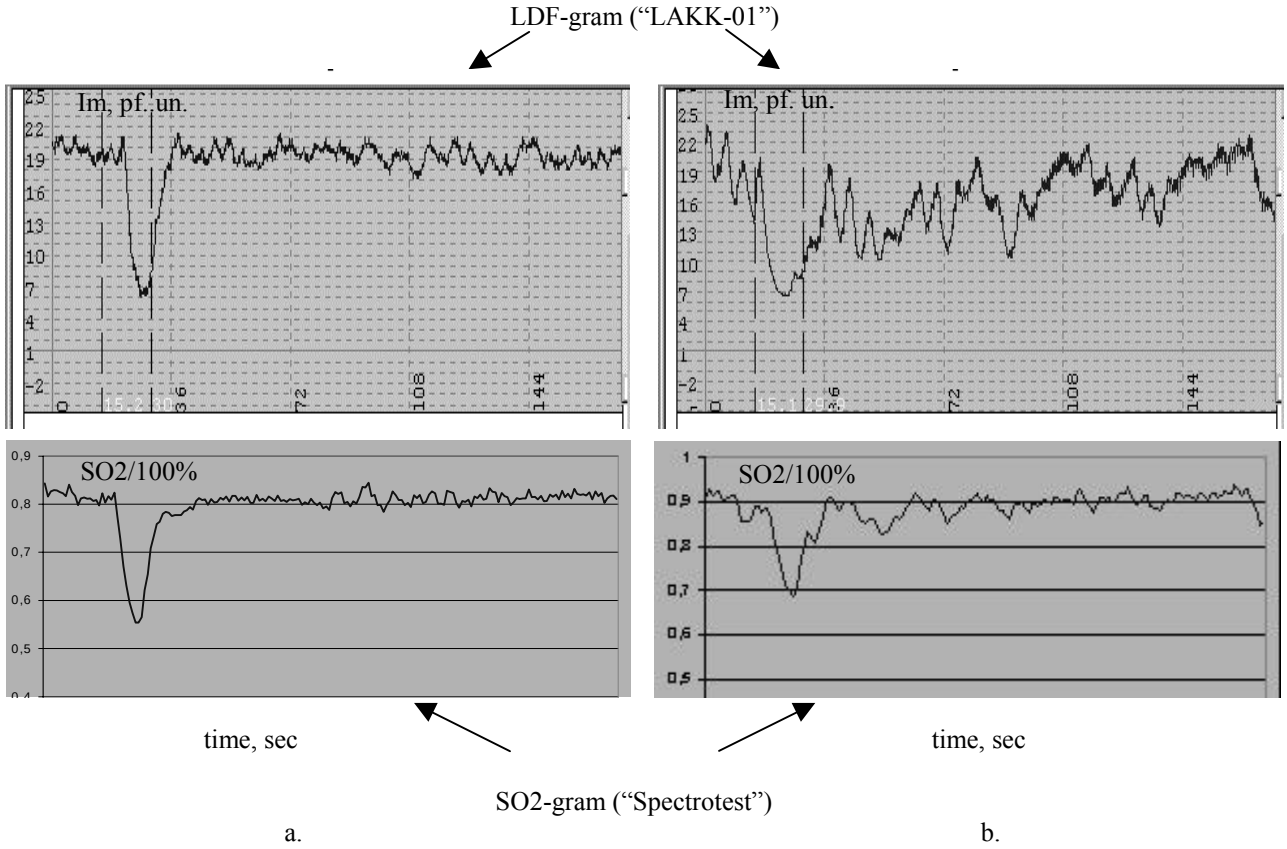

Fig.5. Measured parameters during Respiratory test.
a. Normal case, b. Case of vibration disease.

4. PROSPECTS OF NEW DIAGNOSTIC SYSTEM

According to the received results and conclusions we purpose a creation of new combined diagnostic system. The schematic diagram of that is shown on Fig.7. It will contain the separated RTO and LDF channels. Each channel consists of the laser sources (5, 9), electronic units (1, 8), power supply units (2), photodiodes (3), optical connectors (6) and optical filters (4). The last is used for block the optical signal from other channel. Optical signal flows throw the optical fiber to the tissue and back. After optical - electronic transformation the signal flows to the personal computer (PC). Complex software will produce total data processing. Thus, complex information on a condition of peripheral blood circulation and oxygenation of peripheral blood will be collected from the same area of tested tissues by the single diagnostic system.

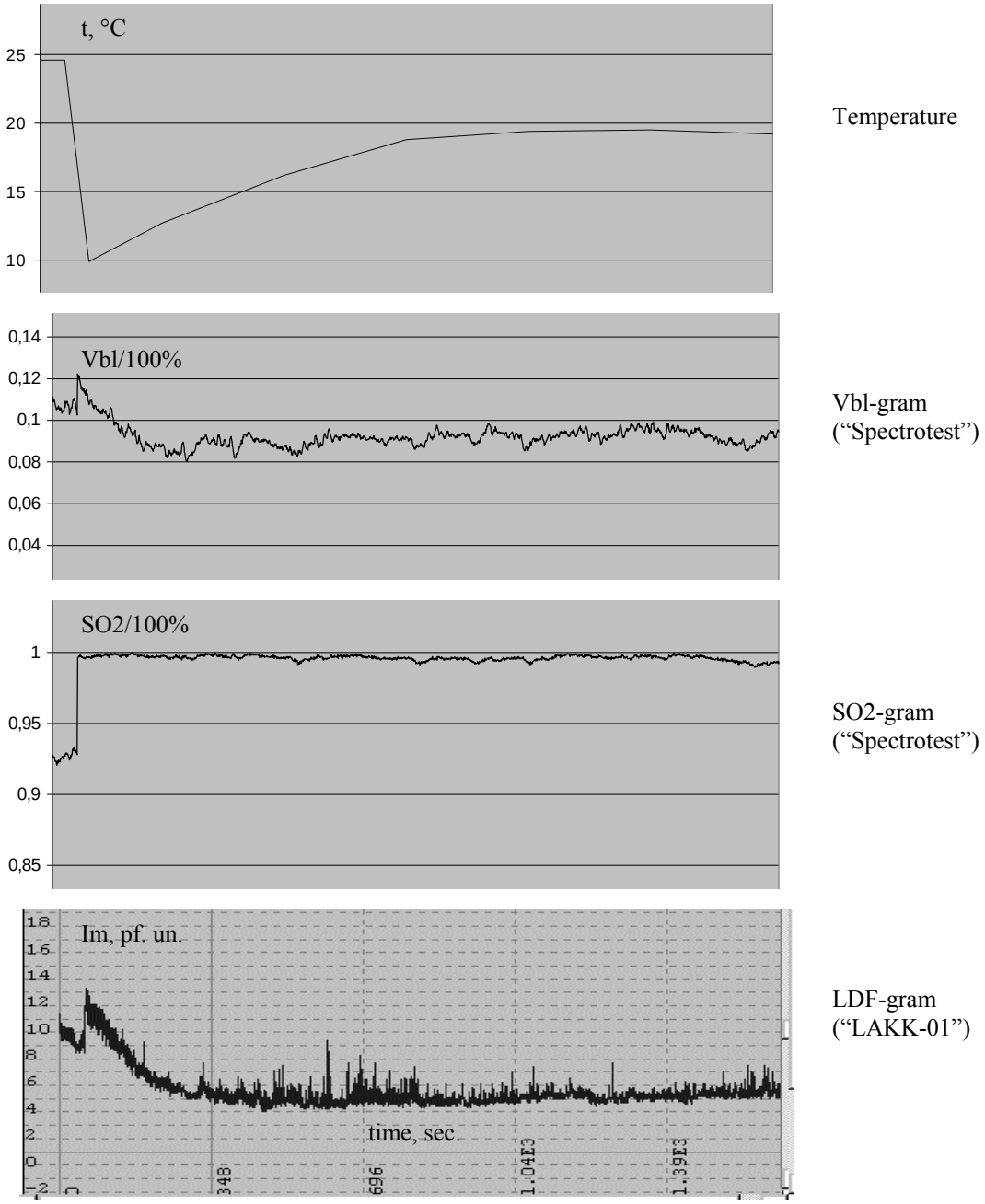

Fig.6. Measured parameters during CT. Vibration disease.
Vbl – fraction of blood volume in a tissue.

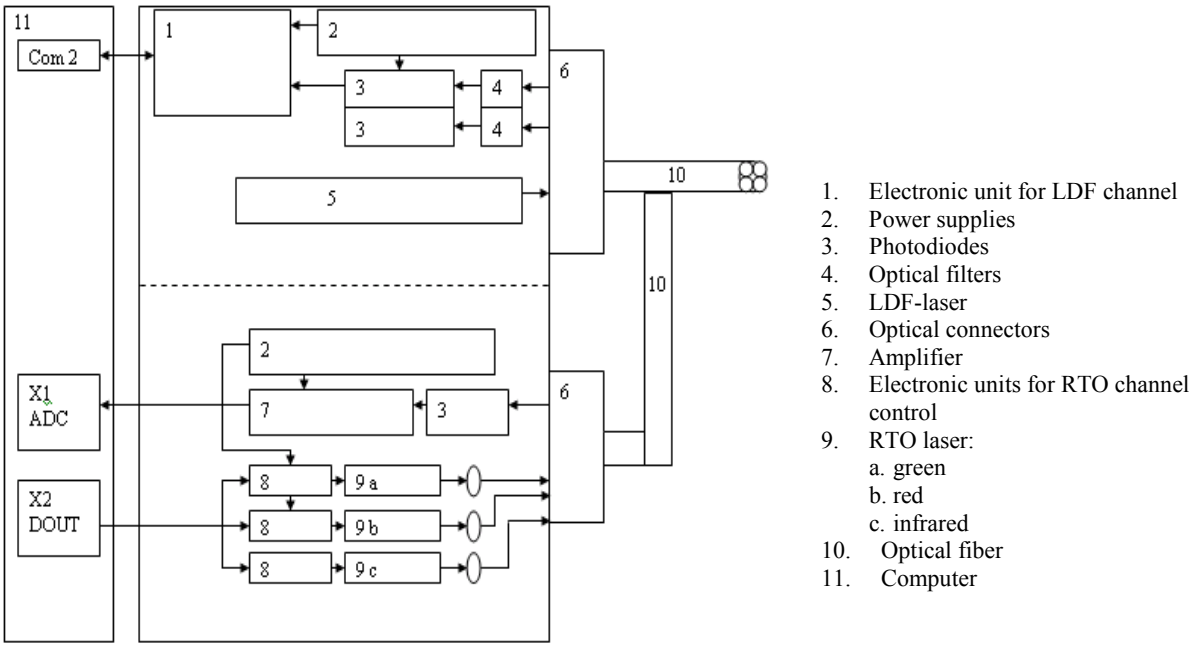

Fig.7. The schematic diagram of new diagnostic system.

5. CONCLUSION

Not touching here the special medical information, we have studied a correlation between LDF and RTO data in a real clinical practice. One of the questions which was important for us is the abilities of "Spectrotest"® to detect a real-time PCBO during different functional tests for the patients with VWF (peripheral blood circulation dysfunctions). We have obtained good results and, in particular, the very surprising correlation between RTO and LDF data, especially in means of detected similar rhythms in original optical signals. On the basis of obtained results we propose a creation of combined diagnostic system with separated RTO and LDF diagnostic channels. We had developed a total block-scheme of the system and hope, that such system will be more useful and informative for the doctor in diagnostic practice.

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