Multifunctional optical processor for biological micro-objects investigation

K. Domnin¹, E. Aksenov¹
¹Saint Petersburg State Polytechnic University, Saint Petersburg, Russia

E-mail: konstant.domnin@gmail.com

Abstract. The combination of two methods: diffractometry and polarimetry was considered. The optical processor device was realized on base of these methods. Biological objects and their phantoms investigations were carried out.

1. Introduction
Optical methods of researches time are usually applied for studying of various objects, including bio-objects at the microlevel. These methods have a huge potential for noninvasive medical express diagnostics.

Different changes at the pathological conditions of an organism courses some deviations in blood morphological and chemical composition. These deviations reflect physiological shifts in organs and their functions, showing pathological processes developing in them.

Abnormalities in morphological composition of blood are expressed in reduction or increase of erythrocytes and leukocytes quantity, in change of uniform blood elements ratios and erythrocytes size and form. At shifts of physical, chemical and biological blood properties it is usually observed viscosity change, violation of blood coagulability process, etc.

Erythrocytes (red blood cells) have a highest sensitivity to any pathologic changes in an organism, therefore they can be convinient objects for research and assessment physiological condition of an organism.

There exist some optical methods for microobjects researches. One of them is a laser diffractometry method, based on diffraction of the laser radiation on a single or multiple biological microobjects [1,2]. This method is characterized by high precision, sensitivity, speed, minimum invasivity, possibility of a huge number of small particles simultaneous registration. The diffraction picture parameters are connected with microobject parameters, so it allows to determine their sizes, form, internal structure.

The other method having a rather high potential for application in bioobjects researches is a laser polarimetry. Polarimetric diagnostics allows researchers to receive information about optical anisotropy of biological tissues.

Optical methods usually allow one to solve problems which are insoluble or difficult for other methods. They are characterized by high sensitivity but make great demands of experiment conditions because of methods high sensitivity to external influences. The potential opportunities of optical processing are obvious: two-dimension research, real time working, high speed processing of big arrangements of data, wide frequencies bandwidth, etc. The theory describing operation of devices is
rather well developed. In connection with this, we determined the objectives of this work: to develop a multifunctional optical processor for biological microobject and its phantoms research.

2. Method and experimental device
The conceptual design of the experimental processor is presented in fig. 1. The device has three information channels: two measuring and one control. To make available an experiment it is necessary to provide a maximum uniformity of object lighting. Uniformity of object lighting can be accomplished due to cut only the central part of the light beam formed by the collimator.

![Figure 1. Structural scheme of experimental setup. 1 – laser, 2,7 – polarizers, 3 – object, 4,6 – beam splitters, 5,8,9 – CCD cameras](image)

This is made by installing a pinhole in a focal spot of the laser beam. For focusing or expansion of a beam it is possible to use a microlens. Behind a lens the spherical front of wave is formed. For receiving the flat wave front it is necessary to add the collimating lens. Thus focus of a lens has to coincide with the central point of a diaphragm. At the exit we receive a parallel beam of light. The diaphragm allows changing diameter of a beam.

Thus, on the transparent with object of interest, placed before a lens, falls the flat wave. In the back focal plane of a lens is formed a complex amplitudes distribution which can be described as Fourier transform of sample transmission function \( t(x, y) \). It is correct irrespective of distance between a lens and the transparent. The additional phase of a spherical wave can be disposed by setting the transparent in the forward focal plane of a lens.

Further there is a division of a light beam into three channels: polarimetric, spectral and visual. In the spectral channel we registered an intensity of the diffraction picture (DP) by means of the CCD camera. Then data were saved on the personal computer and the section of a DP is analyzed. For the data analysis it was used the program “Vision assistant”. It is included in the “National Instruments Vision Development Module” which is intended for engineers and scientists using technical sight devices in industrial and scientific tasks. By means of the vision assistant the received DP were examined. The DP section in various directions were taken and visualized by means of the “Mathcad” program.

In fig.2 and fig. 3 the diffractometric image of blood smear and DP section for transparent with human blood smear are presented. Pictures were taken to define how does erythrocytes transform their shapes in time after blood taken. The diffraction picture became more ellipsoidal after 10 minutes that can specify a change in erythrocytes state, it this case it is supposed that red blood cells formed structures called coins pill. We have seen this structures visually by microscope.
The polarimetric channel registered the image with consideration for polarization and used for detection of an object anisotropy. In this channel in front of the CCD camera was located the polarizer. In experiment two types of measurements were performed: then the polarizer plane of transmission was parallel to the polarization plane of the probing light beam, and then polarizer plane of transmission was perpendicular to the polarization plane of the probing light beam. In fig. 4 and 5 are presented pictures from CCD camera, taken on different transparent in two different output polarizer positions.
Figure 4 Results of research of the plate from glass varnished (the induced anisotropy) on the polarimetric channel. At the left – perpendicular orientation of an output polarizer, on the right – parallel orientation of an output polarizer

Figure 5 Results of research of the human blood placed between subject glasses on the polarimetric channel. At the left – perpendicular orientation of an output polarizer, on the right – parallel orientation of an output polarizer.

3. Conclusion
For carrying out preliminary pilot studies the measuring setup which is based on design model of the processor was mounted. Measurements on channels in the isolated and joint modes were taken. Preliminary measurements within the polarimetric channel of the optical processor demonstrated its sensitivity to objects optical anisotropy, and measurements within the diffractomeric channel proved its sensitivity to the scatters size. Results of measurements under a microscope and the measurements received by a diffractomeric method are in good compliance.

4. References
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