Luminescent imaging of biological molecules and cells on the photonic crystal surface

V.V. Boyko, O.M. Fesenko, G.I. Dovbeshko, V.F. Gorchev, S.O. Karakhin

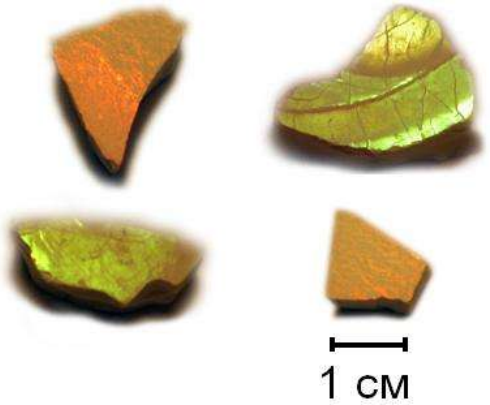
Outline

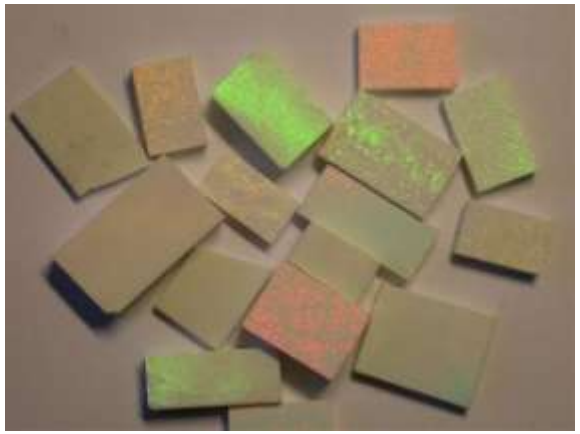
- Introduction
- Characterization of photonic crystals (PC)
- Principles of confocal microscopy
- Imaging of surface of PC
- Imaging of biological molecules and cells on the surface of PC
- Possible mechanism of enhancement of luminescence for molecules adsorbed by the PC
- Summary

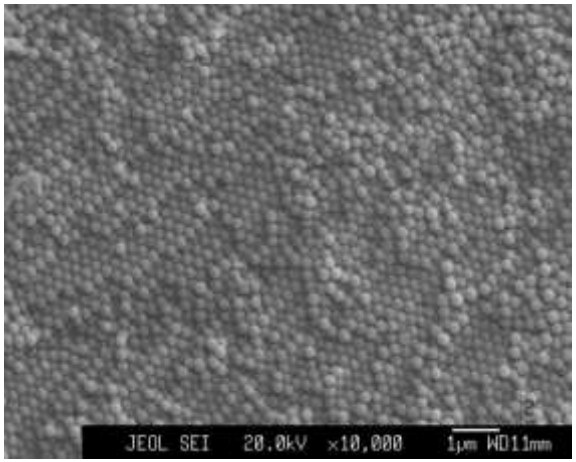
Main goal: to get enhancement the luminescence of biological molecules on the photonic crystal surface and their imaging

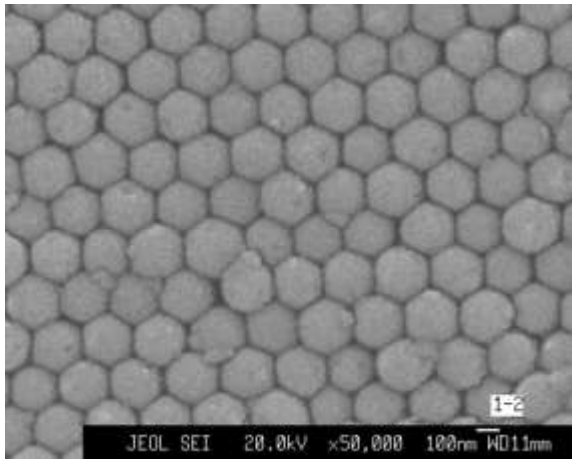
Characterization of photonic crystals

Microstructure (SEM images in SEI mode) of synthetic opals





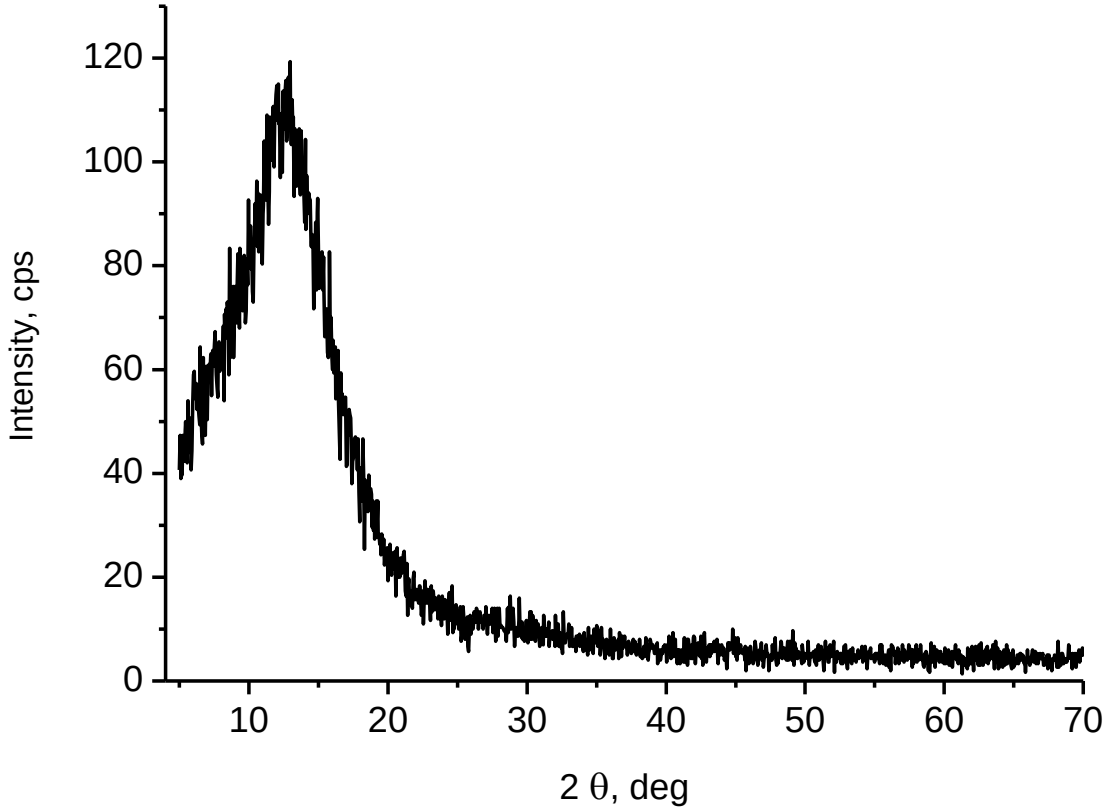




Images of the samples under study

G.I.Dovbeshko, O.M.Fesenko, V.V.Boyko, V.R.Romanyuk, V.S.Gorelik, V.N.Moiseyenko, V.B.Sobolev, V.V. Shvalagin. Secondary emission from synthetic opal infiltrated by colloidal gold and glycine. UJP – 2012. V. 57, №2. P.154.

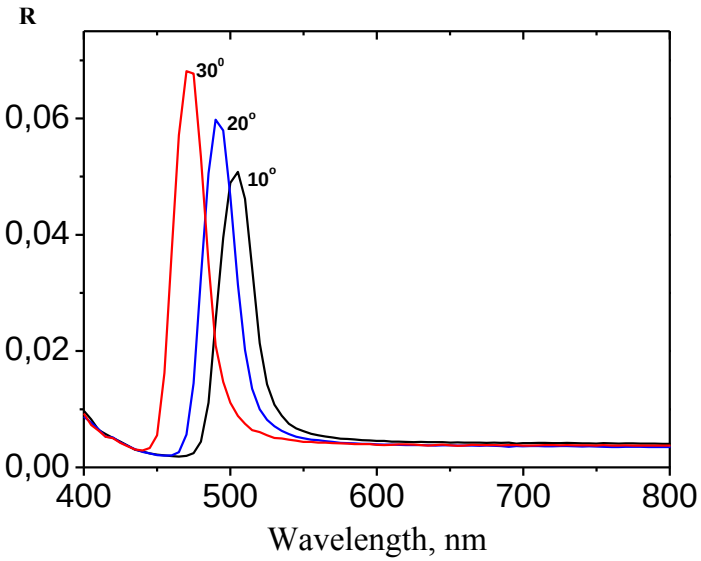
The data of X-ray analysis

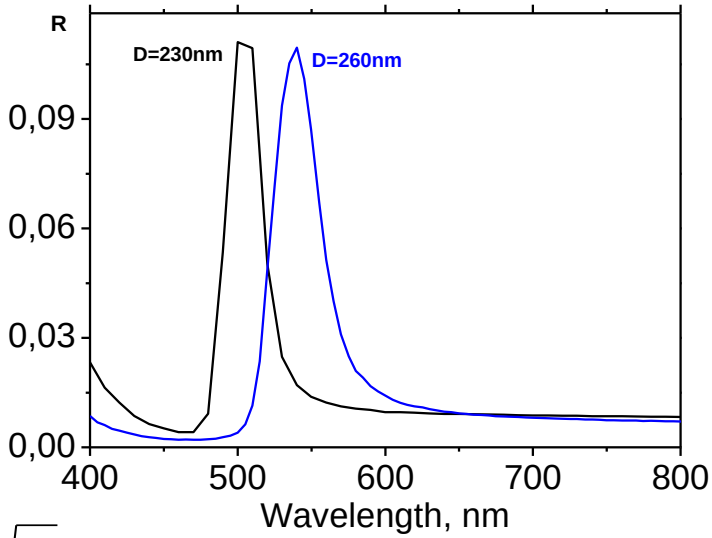


$d = \lambda/2*\sin\theta$, $d = 1.87$ Å

G Dovbeshko, O Fesenko, V Boyko, V Romanyuk, V Moiseyenko, V Gorelik, L Dolgov, V Kiisk, I Sildos. Vibrational spectra of opal-based photonic crystals // IOP Conf. Series: Materials Science and Engineering **38** (2012) 012008

Dependence of Bragg reflection of opals on angle of incidence and diameters of globules





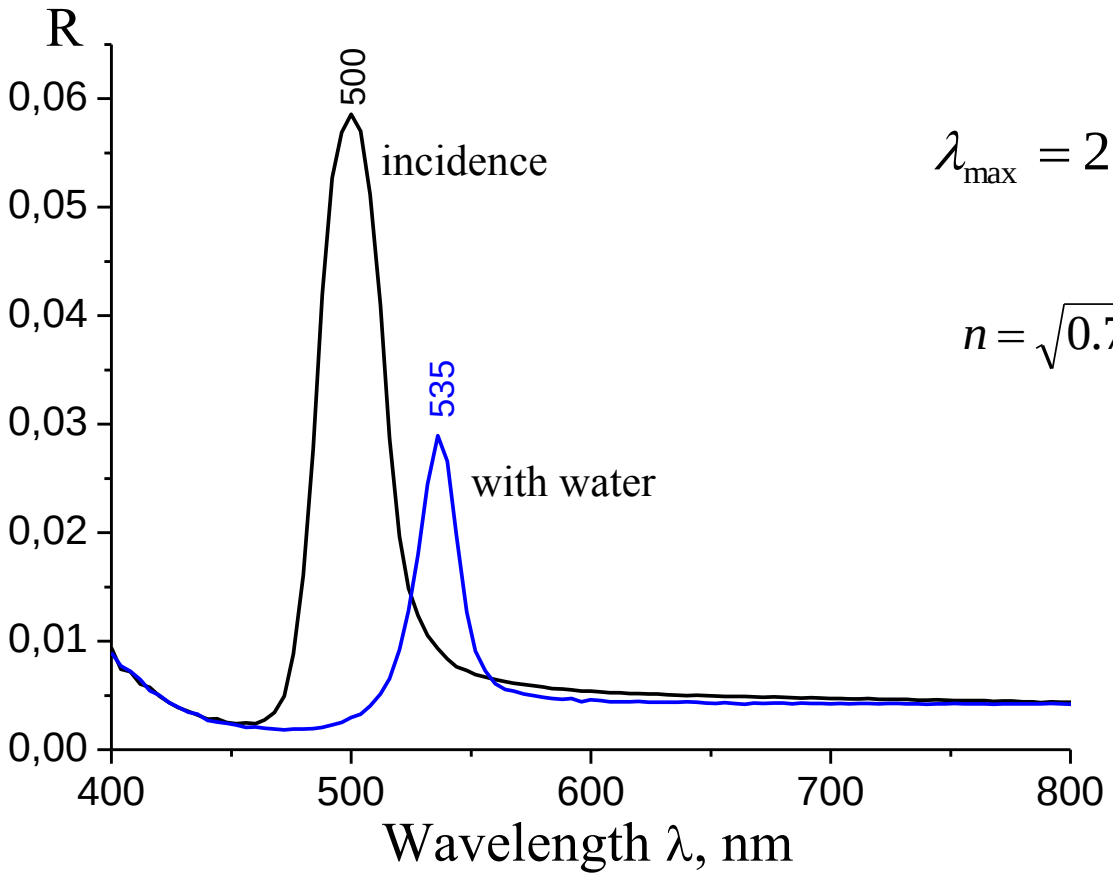
$$\lambda_{max} = 2\sqrt{\frac{2}{3}} D \sqrt{n^2 - \sin^2 \varphi}$$

D – diameter of globules, n – effective refractive index (1.35 [1] 1.39 [2]), φ – angle of incidence.

The positions of the Bragg diffraction shifts in long length under decreasing of the angle of incidence of the beam, this position depends on the globule size.

1. Ю.П. Войнов, Н.Ф. Габитова, В.С. Горелик, Л.И. Злобина, П.П. Свербиль // Физика твердого тела, 2009, том 51, вып. 7, с. 1333-1337
2. А.Н. Грузинцев, Г.А. Емельченко, В.М. Масалов, Е.Е. Якимов // Неорганические материалы, 2009, том 45, №3, с. 302-305
3.G.I.Dovbeshko, O.M.Fesenko, V.V.Boyko, V.R.Romanyuk, V.S.Gorelik, V.N.Moiseyenko, V.B.Sobolev, V.V. Shvalagin. Secondary emission from synthetic opal infiltrated by colloidal gold and glycine // Ukrainian Journal of Physics. – 2012. – Vol. 57, №2. – pp. 154-158.

Dependence of Bragg reflection on effective reflection index



$$\lambda_{max} = 2\sqrt{\frac{2}{3}}D\sqrt{n^2 - \sin^2\varphi}$$

$$n = \sqrt{0.74\varepsilon_{globules} + 0.26\varepsilon_{\text{inf } iltrate}}$$

$\varepsilon_{water} = 1{,}76$

Bragg reflection maximum displays a short-wavelength shift after infiltrated of water in the opal

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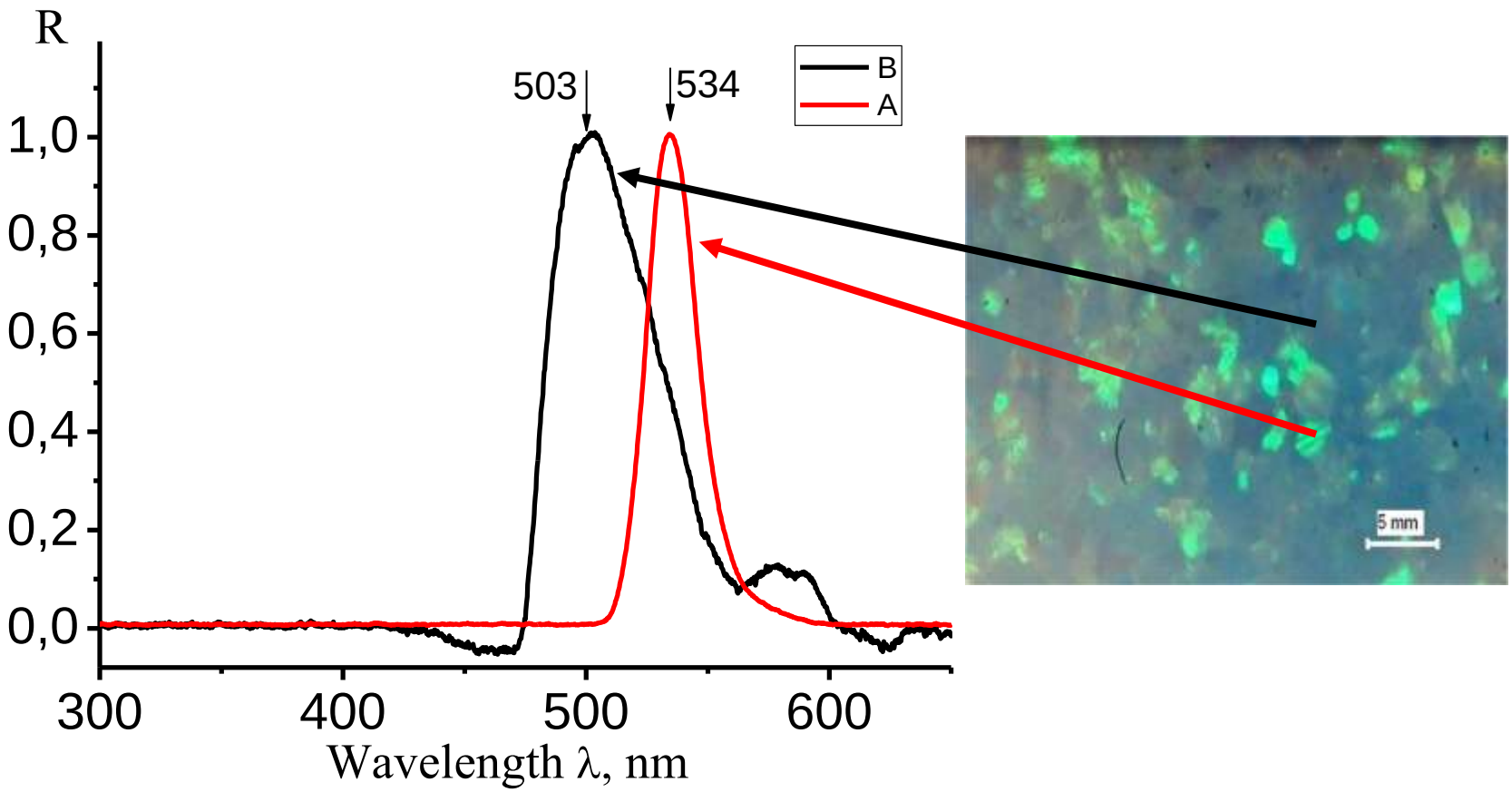
Bragg reflection maximum shift for different domains



Bragg reflection maximum depends on registration place on crystal

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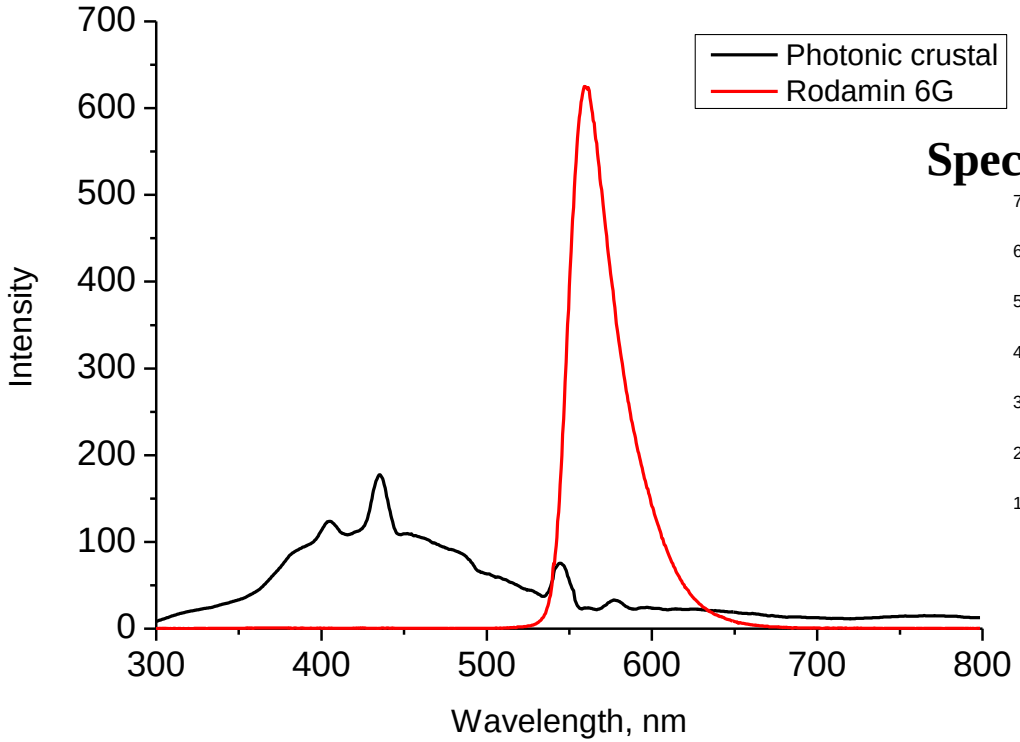
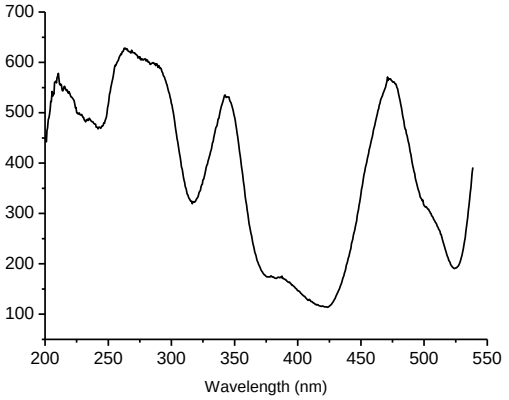
Photoluminescence of PC



Spectrum of excitation of rodamin 6G



Comparison of luminescence spectra of synthetic opal and solution of rhodamine 6G (concentration 10^{-4} mol / l quartz cuvette of thickness 1 cm)

Luminescence of PC consist 10% of intencity of rodamin.

It was shown that own luminescence of PC caused by deffects and admixtures in PC starts from 350 nm and up to 700 nm.

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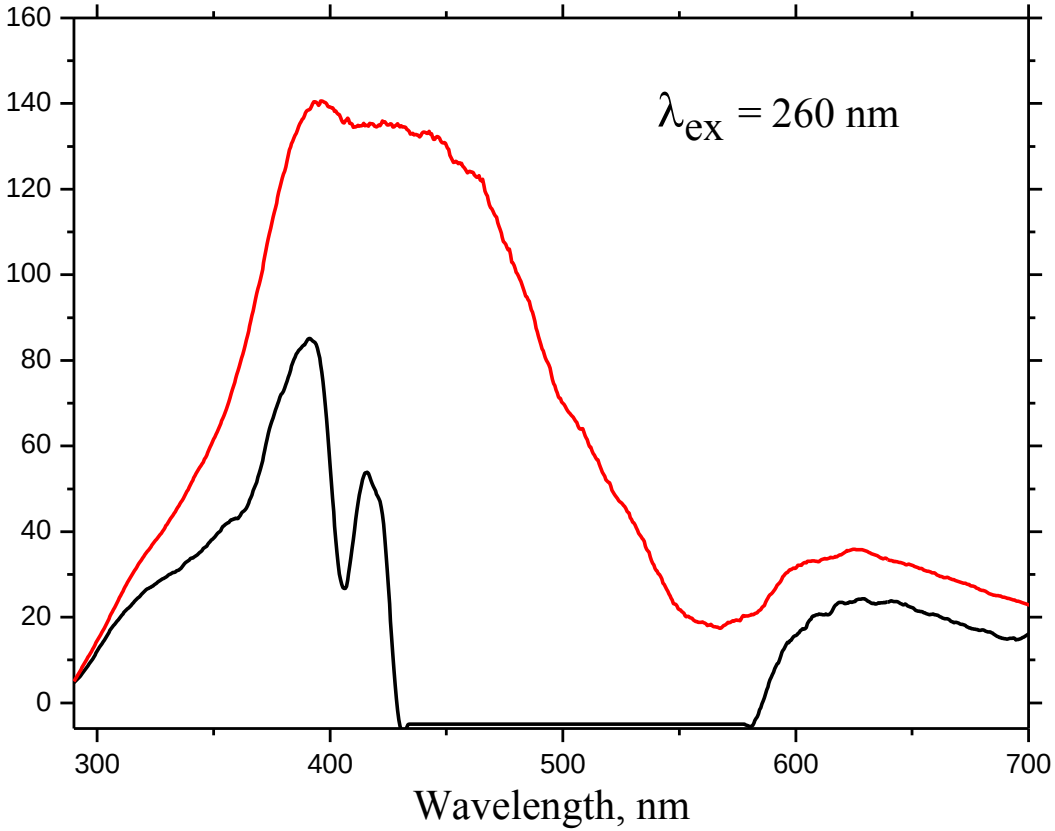
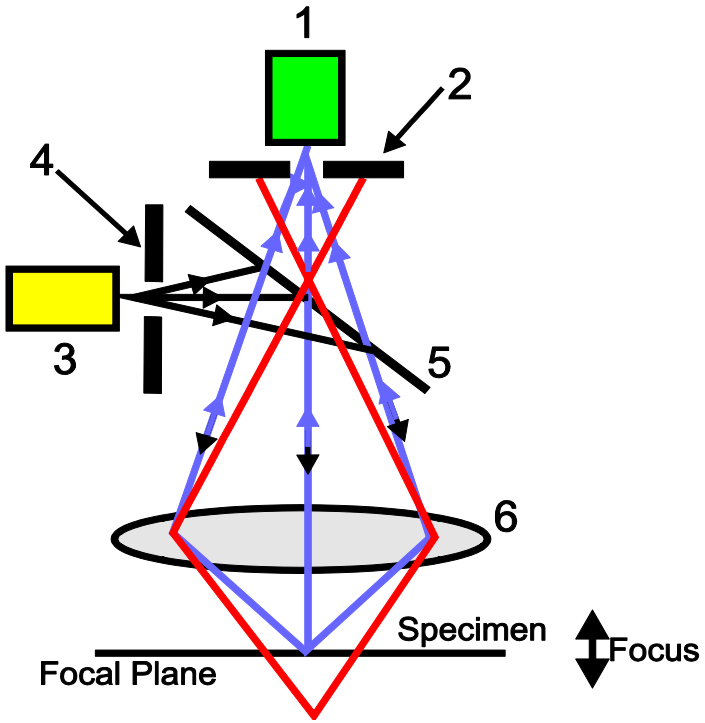
Influence of photonic band-gap on the photoluminescence of PC



Forbidden zone of PC influences the luminescence leading to cutting a part of luminescence range.

Visualization of surface of photonic crystals and biological molecules on the surface of PC

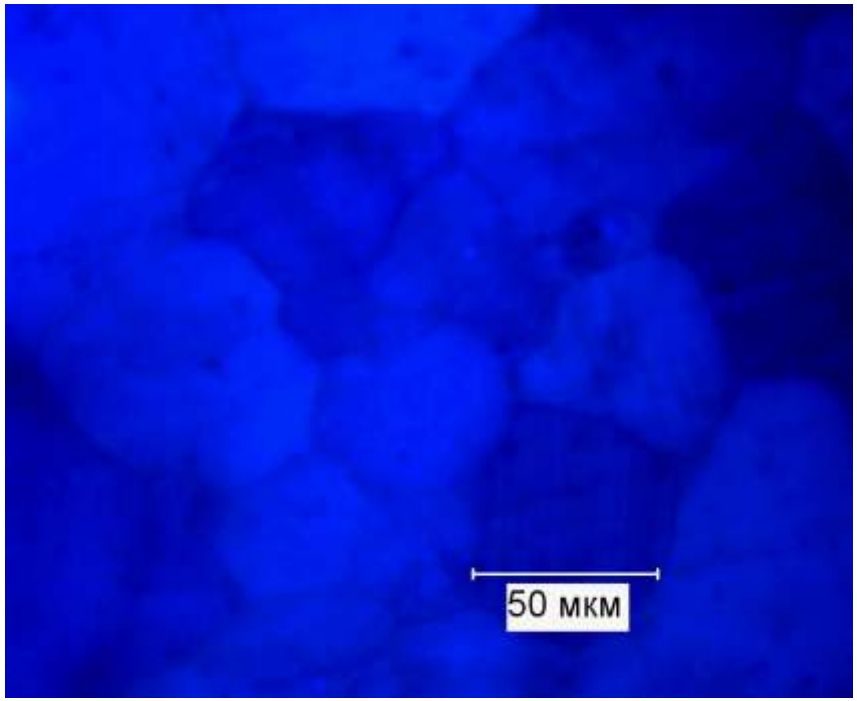
Scheme of confocal microscopy

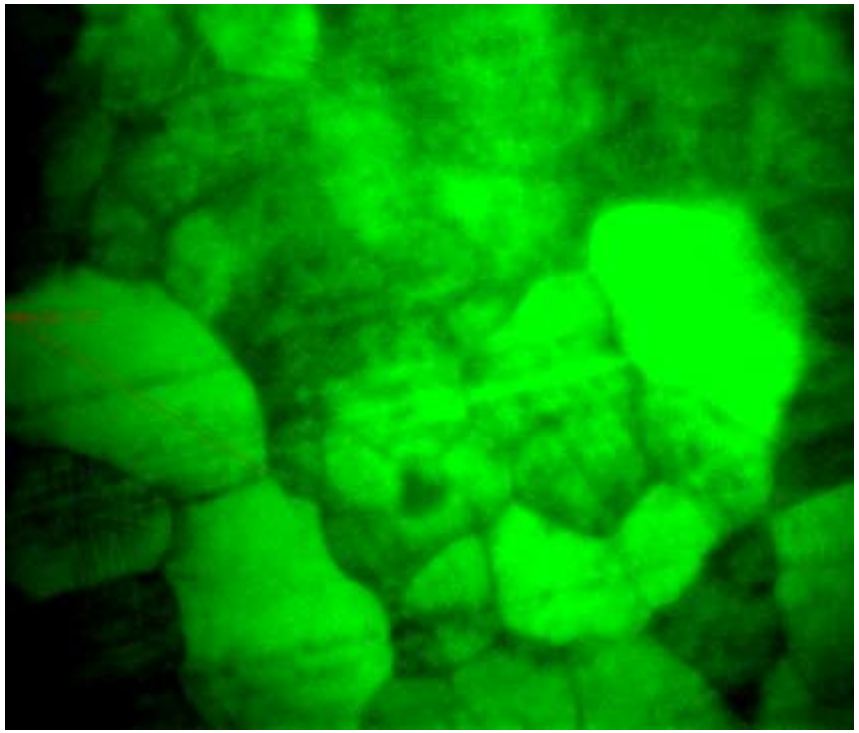


Photodetector - 1,
detector pinhole - 2,
laser or light source - 3,
source pinhole - 4,
beamsplitter - 5,
objective lens - 6.
— In-focus light rays,
— out-of-focus light rays.

We use of confocal laser microscope Carl Zeiss LSM 510 META equipped with an objective Plan-Neofluar 4 0x/0.6 Korr.

Surface of the initial PC





We registered the images of surface of PC domains under its excitation with ultra violet lamp obtained with confocal microscope

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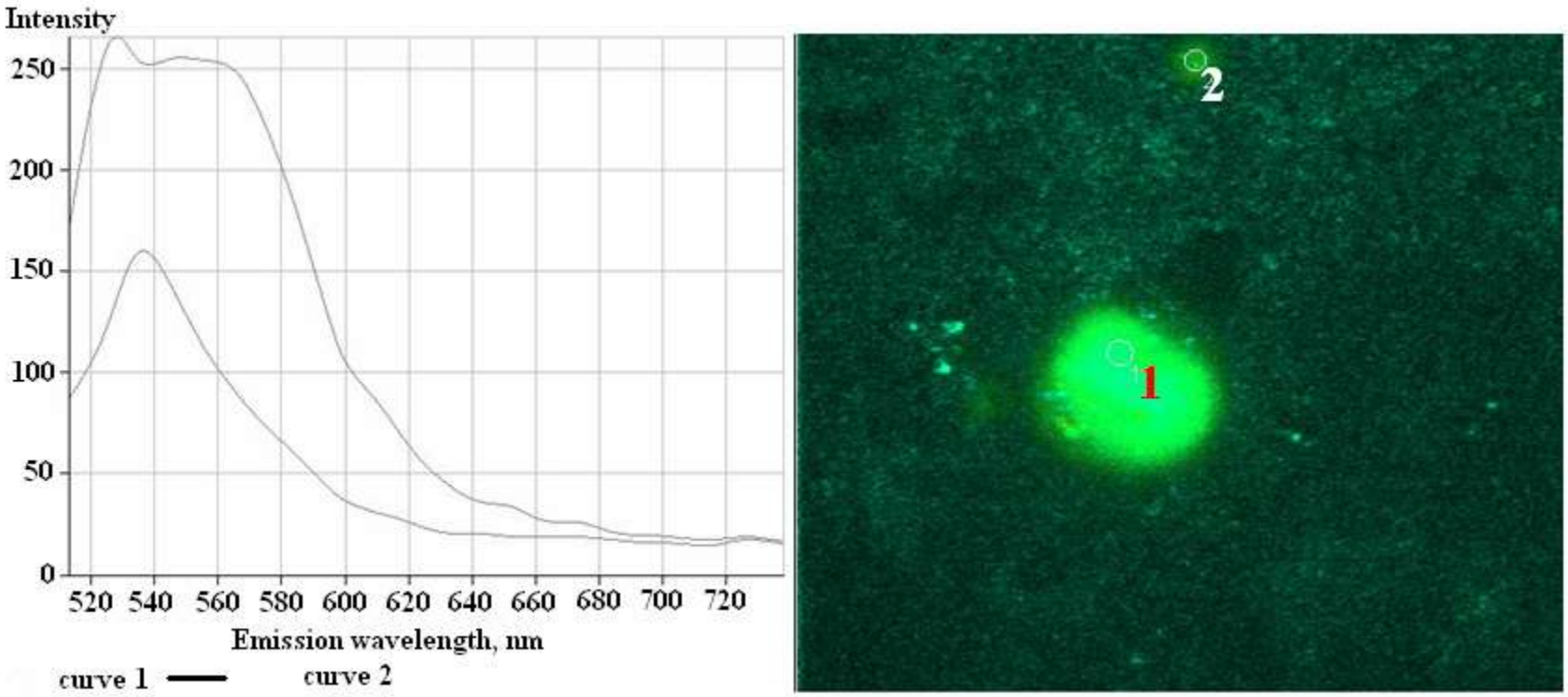
Fluorescence spectra of PC



The fluorescence spectra of synthetic opal from different areas of PC are presented (left) and imaging of this region (right).

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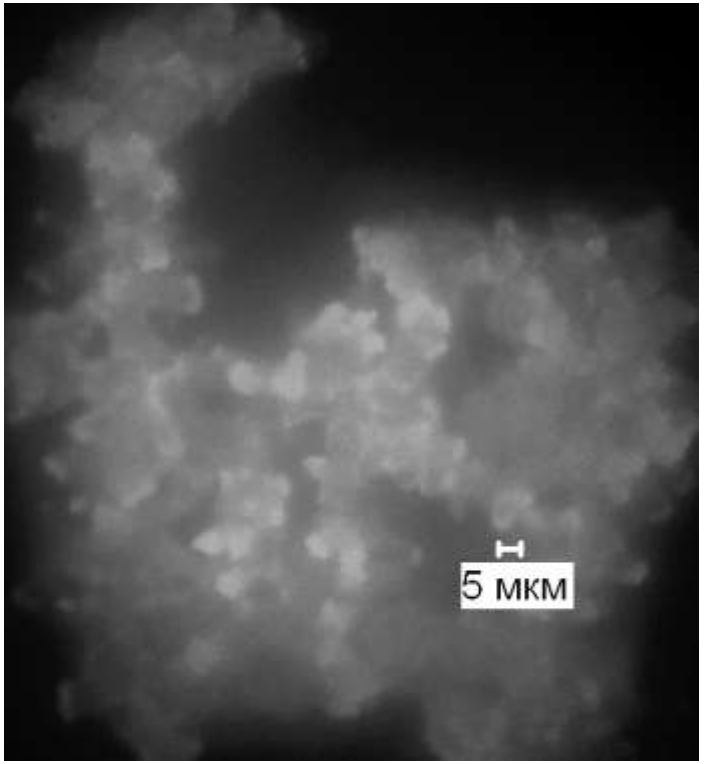
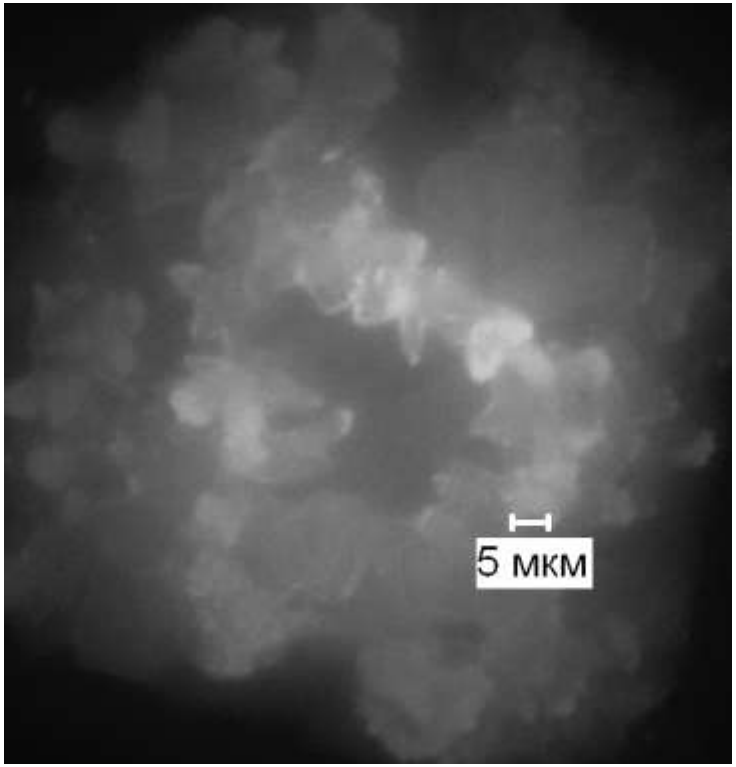
Images of the DNA localized at surface of PC

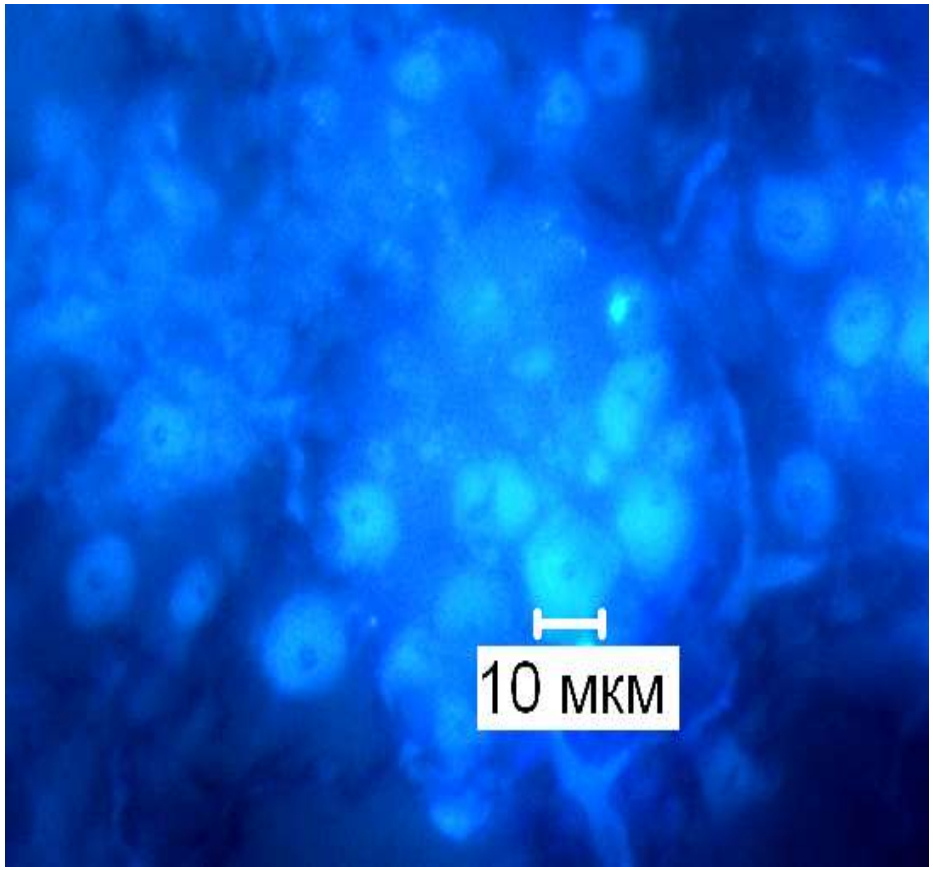


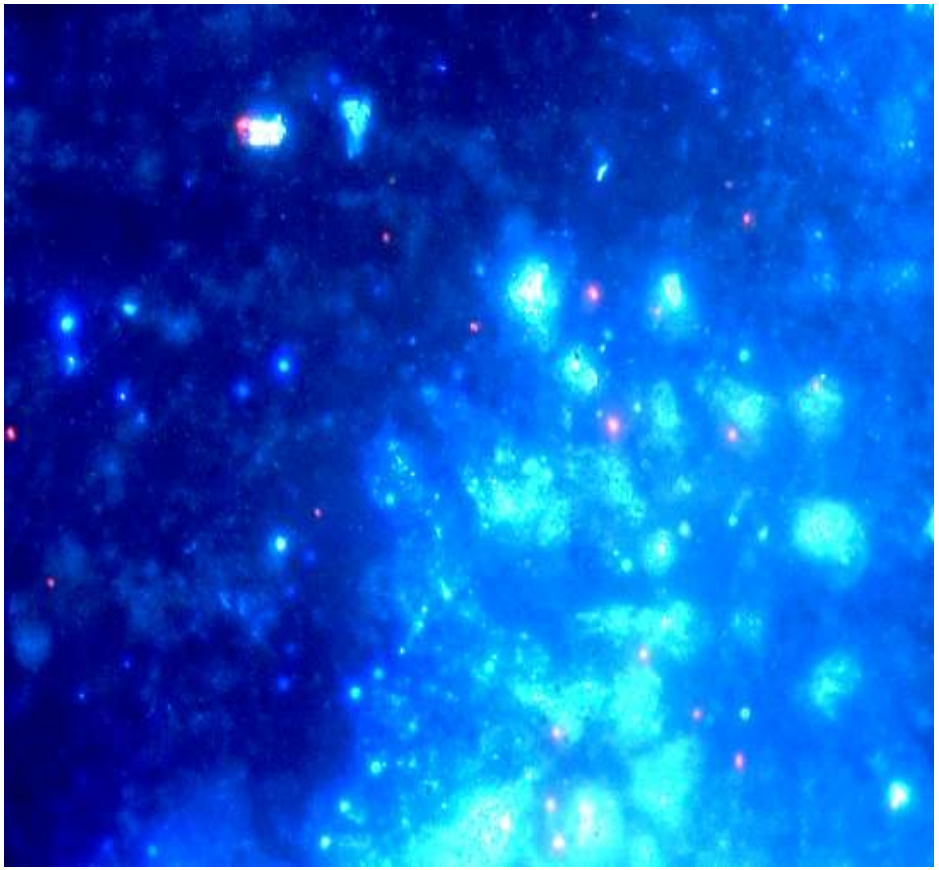


We could get photoluminescence image of clusters of DNA molecules on the surface of PC

V. Boyko, G. Dovbeshko, O. Fesenko, V. Gorelik, V. Moiseyenko, V. Romanyuk, T. Shvets, P. Vodolazkyy. MCLC. – 2011. V. 535. P.30.

Optical imaging of blood cells on the surface of PC





erythrocytes **blood cells**

Photoluminescence images of blood cells and erythrocytes deposited onto surface of PC
This images gives us a possibility to characterize the types of cells using their shapes

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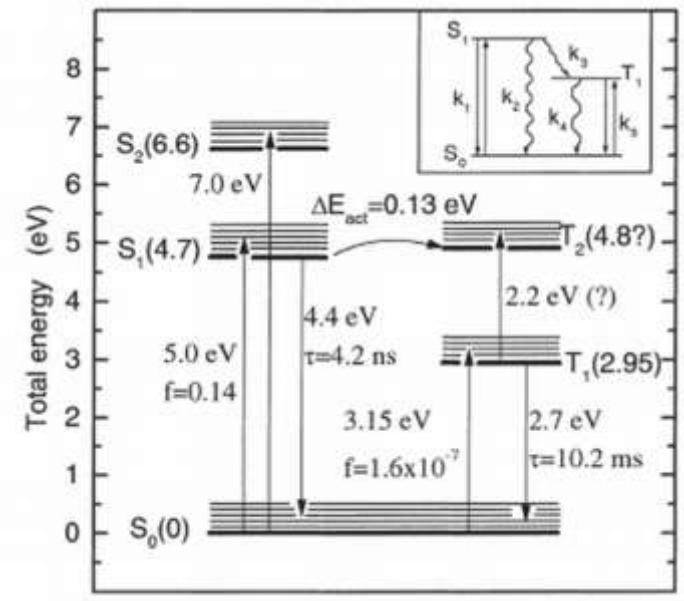
Possible mechanisms of the effects



Energy levels defects of PC and biological molecules

	dCMP	dGMP	dTMP	dAMP
	eV			
S_1	4,1	4,09	4,15	4,27
T_1	3,3	3,26	3,24	3,21

- We could get imaging of DNA and cells due to the fact that PC and DNA has close excitation energy triplets and singlets. Possible mechanism of transfer energy from PC to DNA probably takes place here.
- To clear up the mechanism we are going to measure time decay luminescence.

Conclusion

- The PC has luminescence in the region of 350-700 nm.
- Photoluminescence images of biomolecules deposited onto surface of PC gives us a possibility to characterize the cells and their components.

Acknowledgment

- Ukrainian-Russian project № 60-02-12 and STCU № 5525 for financial support
- Prof. Gorelik V.S. and prof. Moiseenko V.N. for samples of synthetic opals and discussion of results
- Dr. Gridina N.Ya. for preparation of samples of biological cells.

THANK YOU FOR ATTENTION!