NATIONAL ACADEMY OF SCIENCES OF BELARUS

B.I. STEPANOV
INSTITUTE OF PHYSICS

MINSK 2022

CATALOGUE OF DEVELOPMENTS & SERVICES

State Scientific Institution "B.I.Stepanov Institute of Physics of the National Academy of Sciences of Belarus"

B.I.Stepanov Institute of Physics of the National Academy of Sciences of Belarus starts from the sector of physics and mathematics organized in 1953 in Physical-Technical Institute of the Academy of Sciences of BSSR by academicians A.N.Sevchenko and B.I.Stepanov invited for a constant work in Minsk from Leningrad and F.I.Fedorov who was the Chief of Theoretical Physics Department of Belarusian State University. On the basis of this sector, consisted of 10 employees and 3 post-graduate students, the Institute of Physics and Mathematics of the Academy of Sciences of BSSR was formed on January 17, 1955. It was the first independent physical-mathematical research center in Belarus. The first Director of the Institute of Physics and Mathematics from 1955 till 1957 was Anton Nikiforovich Sevchenko, in 1957 he became the Rector of Belarusian State University. In June 1959 the mathematical part of the Institute employing many people by that time was reorganized to the Institute of Mathematics and Computer Engineering of the Academy of Sciences of BSSR and the physical part employing about 90 people by that time was called the Institute of Physics. From January 1988 the Institute is named B.I.Stepanov Institute of Physics of the National Academy of Sciences of Belarus. At the request of the team, the Institute was named after Boris Ivanovich Stepanov who was the Director of the Institute from 1957 till 1985 to memorize his great contribution to the creation and development of the Institute.

Stepanov Boris Ivanovich (1913-1987) – founder of the Institute of Physics and its Director from 1957 till 1985.

An outstanding scientist in general spectroscopy, molecular spectral analysis, luminescence, laser physics, nonlinear optics. Hero of Socialist Labor, Honored Science Worker of BSSR, Laureate of State Prizes of USSR and BSSR, Academician, Dr. Sci. in Physics and Mathematics, Professor.

Together with A.N.Sevchenko, B.I.Stepanov and F.I.Fedorov an important role in organization and development of the Institute was played also by N.A.Borisevich who was the Deputy Director on Science from the day of establishment of the Institute and till 1969 when he became the President of the Academy of Sciences of BSSR, and also by M.A.Ilyashevich who was an elected Academician of the Academy of Sciences of BSSR and moved to Minsk in 1956 from Leningrad.

Even before the Institute was established its organizers had conducted a great work on selection and teaching the scientists, formation of topics for future investigations. As a result of this activity the Institute grew rapidly, in fifties a wide front of scientific works was conducted in the following areas: spectroscopy and luminescence of complex molecules in solutions and vapors, optics of anisotropic and scattering media, spectroscopy and diagnostics of low-temperature plasma, elementary particles theory. Since 1961 the major directions of scientific investigations of the Institute have been laser physics, nonlinear optics, and laser spectroscopy.

As it is known the first laser was produced in 1960 in the USA. B.I.Stepanov and leading scientists of the Institute realized that the discovery of lasers is a principally new stage in the development of optics and its applications, scientists of the Institute started the development of this direction immediately together with their colleges and students. They found out that lots of methods and approaches previously developed in the Institute could be applied in the new investigation area and many scientists were well prepared to new ideas and effective work in this area. The Institute possessed the atmosphere of creativity, investigations and scientific works of the Institute were not only leading for laser physics and nonlinear optics but often they determined the development of this scientific front. Intensive theoretical investigations were conducted, and after 1963 when the first laser was launched in the Institute by V.A.Pilipovich intensive experimental work started as well.

In the sixties, due to the level and volume of investigations, quality of the obtained results, wideness of the observed scientific topics the Institute of Physics became one of the leading scientific centers of the Soviet Union on laser physics, physical optics, optical spectroscopy and physics of plasma. In 1964 Presidium of the AS of BSSR authorized the Institute for publishing the all-union "Applied spectroscopy journal". In 1965 the first in the USSR open symposium on nonlinear optics and laser physics (ICONO) was organized by the Institute near Naroch Lake. From this moment various International conferences on laser physics, coherent and nonlinear optics were systematically held in the USSR and also after breakup of the Soviet Union. Before Naroch symposium the discussion of laser physics problems in the USSR was held only in closed meetings of scientists. In 1967 the Institute of Physics first of all the Institutions of the Academy of Sciences of BSSR was awarded the Order of the Red Banner of Labor for great success and highly-qualified scientists. The following facts helped the Institute to become a large successful scientific center: for a short period of time the Institute managed to start an active work over the actual physical problems of that time, to employ talented creative hard-working stuff, to organize specialized design-technological department with experimental production (DTD EP) for experimental-technological developments and production of complex devices and set-ups on the high level. Laboratories of the Institute had an opportunity to create end upgrade their technical base and make experimental samples of the devices.

Foundation and development of the Institute of Physics coincided in time with rapid revolutional transformations in optics and spectroscopy. Necessity of solving such questions as problems of operation of rocket engines and rocket airfoil at movement in the atmosphere, development of precise and fine technologies provided a high demand for the spectral and optical investigations and developments. Lasers discovery led to the breakdown of many principal and immutable concepts and ideas in optics. An opportunity of using the light not only for light-technology and studying the structure and properties of substance but also as powerful tool for various objects studying as well as for processing and transfer of the information appeared. Many new scientific directions and sections appeared in optics itself and optics with other sciences jointly. A rapid growth of the stuff of the Institute had continued about 20 years. In the second part of the seventies it stopped at the number of a little more than 1300 employees, including 500 employees in DTD EP and 150 employees in Mogilev branch, formed in 1970.

The volumes of investigations and developments of the Institute stabilized though the demand for them was high as before. Research areas still corresponded to the world tendencies of the developed scientific directions and application needs, creative cooperation with many Academic Institutions, High Education Institutions, Scientific Institutions and Design-Technological Bureaus of the country kept strengthening and widening, the Institute actively participated in the execution of State Programs and Tasks, often as the Head Organization. The Institute cooperated with the Scientific Institution for Space Investigations on the problems of space spectrometry of landscape and other objects on the surface of Earth, the devices showed stable work on space stations. According to the task of Hydrometeorological Centre of the USSR, the Institute participated in the creation of the system of laser Lidar stations for stratospheric research. Relations with BelOMO kept strengthening as well.

In 1979 on the basis of the Institute an Interagency design-technological department (having two Head organizations – AS of BSSR and Ministry of the Defense Industry), the work of which allowed using the scientific results of the Institute for solving the optical tasks of the Defense Industry.

In 1984 Minsk Experimental-Industrial Enterprise of the Unique Instrumentation of the AS of USSR started working. One of the tasks of this enterprise was to replicate the developments of Belarusian scientists. Serial production of devices and laser-optical equipment elements designed by DTD EP of the Institute was organized. It should be noted that building and starting of this enterprise were controlled by the President of AS of BSSR N.A.Borisevich and the Institute of Physics. A great contribution to the organization of this enterprise was made by V.S.Burakov who was the Deputy Director of the Institute of Physics and then the first director of the enterprise.

The Institute of Physics & Mathematics (before it was separated, 1959)

Results of scientific activity and applied research of the Institute of Physics during the Soviet period are marked with 2 Lenin Prizes, 8 State Prizes of USSR, 8 State Prizes of BSSR, 10 Prizes of VLKSM and LKSMB (Lenin Komsomol), and many other medals and orders. Founders of the Institute and well-known scientific schools A.N.Sevchenko, B.I.Stepanov, F.I.Fedorov and N.A.Borisevich were awarded with the title of a Hero of Socialist Labour.

The most essential results of this period can be as follows:

- theory of luminescence and light absorption by complex molecules and semiconductors was developed, a number of principal questions of general spectroscopy were solved. Regularities of manifestation of heat radiation background in spectral-optical experiments were revealed as well as the correlation between absorption and luminescence spectra named then "Universal Stepanov relation". In 1967 B.I.Stepanov was awarded with S.I.Vavilov Golden Medal "For Outstanding Achievements in Physics" by Presidium of AS of USSR.
- covariant theory of electromagnetic and acoustic waves in anisotropic media and their border was developed, the phenomenon of lateral shift of a light beam as a result of total internal reflection ("Fedorov effect") was discovered, calculation of a large number of crystal-optical elements for laser technology was accomplished.
- spectroscopy of free complex molecules was developed. The processes of thermolization of oscillatory movement of excited molecules in vapors were studied in details. The phenomenon of stabilization – labilization of electron-excited complex molecules, was registered by N.A.Borisevich and B.S.Neporent (SOI, Leningrad) as a discovery; laser generation in complex molecules vapor was obtained.
- spectral-luminescent properties of chlorophyll molecules, porphyrins and related compounds were investigated in detail, the role of singlet oxygen in the photooxidation and photodestruction processes was revealed, the phenomenon of photoburning of holes in melalloporphyrine spectra was discovered and studied.
- methods and equipment complexes for investigation of a plasma under laboratory and natural conditions were developed, including plasma of rocket airfoil at movement in the atmosphere, as well as aero-space remote spectrometry of natural objects were developed.
- laser generation on the basis of dye solutions was obtained, sources of high-coherent radiation with tunable frequency including distributed-feedback lasers were developed and designed, a number of dyers providing laser radiation in the whole visible range were revealed.
- calculation and systematical analysis of the dependence of energy and temporal characteristics of lasers on the parameters of resonator, active medium and pumping was conducted.
- operation of semiconductor lasers and lasers on quantum-dimensional heterostructures were studied in details, new types of diode-pumped, optically-pumped and electron-beam-pumped semiconductor lasers were designed.
- patterns of simulated Raman scattering, harmonics generation, frequencies addition and subtraction, laser beams self-focusing and defocusing were studied theoretically and experimentally. Nonlinear-optical frequency convertors allowing to obtain laser radiation in infrared, visible and ultraviolet regions of spectrum were designed.
- physical bases for dynamic holography were developed, new methods for transformation of light beams spatial structure were proposed, the phenomenon of phase conjugation of light beams in four-photon interactions was discovered.
- regularities of light scattering in hydrosphere, atmosphere, various natural and artificial media were studied theoretically and experimentally. On this basis effective methods and equipment for characteristics determination of atmosphere, water and other objects including multiwave laser testing were created. A number of problems with vision, location and communication via scattering media were solved.
- on the basis of deep study of radiation dispersion in powder media dispersion filters for infrared radiation were developed and designed.

- regularities of Gaussian beams propagation in anisotropic and multilayer media were studied, including anisotropic optical waveguides. Technologies for obtaining the elements of planar integral optics were developed.
- large-scale introduction of methods of atomic and molecular spectral analysis into the enterprises of the Republic of Belarus was realized. New methods of determining the properties of carbohydrates and proteins, polymer materials, flax fibre etc. were developed.
- the influence of a powerful laser radiation on spectral-optical characteristics of resonance media and processes of relaxation was analyzed in details.
- the phenomenon of splitting the spontaneous absorption and emission lines into three components under the influence of powerful resonance radiation was predicted. The phenomenon of grouping and anti-grouping of resonance fluorescence photons was predicted.
- new methods of laser spectroscopy were developed, and unique spectrometers with intra-resonator absorption, coherent four-wave shift and high temporal resolution were developed.
- regularities of generation of polarized radiation were revealed, and methods of polarization laser spectroscopy were developed.
- physics of plasma-dynamic processes arising under the influence of laser radiation on the surface of solid bodies was studied, a number of patterns of laser-plasma influence on composite materials were revealed.
- methods and devices for laser therapy of a wide range of diseases were developed, including infants jaundice, diseases of eyes, oncological diseases. Devices developed and produced in the Institute are successfully used in Belarusian hospitals and abroad.
- great contribution to the investigation and creation of the prototype of laser gyroscope based on a ring laser with anisotropic resonator and active medium in the magnetic field was made.

The Institute of Physics has always worked in spectral-optical direction of investigations, including laser physics and physics of plasma. However the investigation in physics of elementary particles and nuclear spectroscopy were always conducted in the Institute. First of all these were works of a large scientific school of F.I.Fedorov. F.I.Fedorov, A.A.Bogush, L.M.Tomilchik, L.G.Moroz and their students successfully developed invariant methods allowing calculation of the state and interaction of the fields and elementary particles, a number of processes and reactions in the area of physics of high energies were calculated. In the Laboratory for Nuclear Spectroscopy led by E.A.Rudak 32-crystal gamma-gamma spectrometer and 6-crystal gamma-spectrometer “Prypiat” were created. These devices allowed measuring the level and composition of radionuclide contamination of various objects. Eight devices “Prypiat” were delivered to the organizations dealing with problems of Chernobyl accident consequences.

In 1989 a hard period started for the Institute of Physics. This year the financing of works on the orders of directive organs was reduced and in 1992 the financing was completely stopped. The absence of financing placed the Institute in a very difficult situation, as directive orders made about 70% of all activity of the Institute and contract-based research made more than 80% of all activity of the Institute. Moreover, in that time the Institute faced to the general problems of all scientific organizations connected with the breakup of the Soviet Union.

1989-1991 years were the most difficult for the Institute. The Institute lost more than 30% of the stuff. There was no opportunity of upgrading the technical base of the laboratories in DTD EP. This department of the Institute was reorganized to the independent organization “Axicon” which could take orders from other organizations.

Other structural changes occurred as well. In 1991 the Laboratory for Optical problems of Informatics led by A.M.Goncharenko became an independent Department at the Presidium of NAS of Belarus, and in 1992 Mogilev branch of the Institute was reorganized into the Institute of Applied Optics of NAS of Belarus. On the basis of ten laboratories of spectral-luminescent and plasma profile the Institute of Molecular and Atomic Physics (IMAP) of NAS of Belarus was formed. Nevertheless, the remaining team was still relatively large, consisting of 19 laboratories, with more than 240 employees, including 37 Dr.Sci. and about 150 PhD in physics and mathematics.

The situation turned for better after the formation of the independent Republic of Belarus.

Entrance to the Institute of Physics from the side of Surganov street.

The government of our country paid considerable attention to the scientific sector: state research and development programs (SRDP) and scientific and technical programs (SSTP) were organized, before the breakup of the USSR the Belarusian Republican Foundation for Fundamental Research (BRFFR) was created. After the breakup of the Soviet Union, various International Funds for Science Support operated for some time, especially in organizations that had previously actively collaborated with the military-defense complex of the USSR. The Institute of Physics and organizations separated from it took an active part in the formation and implementation of projects under these programs, grants from National and International Funds.

At the same time the contacts with foreign scientists widened, trips to international conferences (with financial support from conference organizing committees) significantly expanded, and the performance of experimental research on the equipment of foreign organizations became possible. All this allowed one to save previously accumulated scientific potential and to gain working experience in new conditions relatively quickly. At this time the activities of the Institute of Physics and the Institute of Molecular and Atomic Physics were awarded with 9 State prizes of the Republic of Belarus, and many orders and medals of the Republic of Belarus, Diplomas of the President and Council of Ministers of the Republic of Belarus.

In 2007 by the decision of the Presidium of the National Academy of Sciences of Belarus the Institute of Molecular and Atomic Physics, the Institute of Electronics, and the DTB “Axicon” were added to the Institute of Physics. In 2004, the Department of Optical Problems of Informatics at the Presidium was transformed into the laboratory of the Institute of Physics. So at present B.I.Stepanov Institute of Physics is the largest Institute in the National Academy of Sciences of Belarus.

It consists of 14 scientific centers and 1 research and production center, with the stuff of 355 employees, including 36 Dr.Sci. and 96 PhD, 6 Academicians and 6 Correspondent Members of the National Academy of Sciences of Belarus. 13 employees have the title of Professor and 19 the title of Associate Professor. The Institute includes:

- Fraunhofer–Stepanov International Laboratory for Optical Diagnostics;
- Laboratory for Nonlinear Optics has the status of a research center of the secondary network of the Central European initiative;
- Belarusian-Vietnamese Laboratory for Laser Physics, engineering and technology;
- International organization ICRANet-Minsk.

Besides, three applied-research laboratories are established and work actively in the Institute: applied-research Laboratory for Molecular - Beam Epitaxy of Nitride Heterostructures; applied-research Laboratory for Optoelectronic and Fiber - Optic Technologies for creation of diagnostic and measuring systems (together with SSPA "Optics, optoelectronics and laser technology"), applied-research Laboratory for Industrial Testing of Laser and optoelectronic Equipment.

At present the Institute of Physics works in the following main directions:

- Laser physics, development and fabrication of laser systems and technologies of their application in medicine, ecology, metrology, industry, ect.
- Physical and nonlinear optics, revealing and application of regularities of powerful laser radiation propagation in various media.
- Optical spectroscopy, development and application of methods and devices for investigation of properties and structure of various materials including biological tissue.
- Nano-optics and nano-materials, investigation and development of questions of practical application of nano-structures.
- Micro- and optoelectronics; research of properties and structure of microelements of electronics, development of problems of their practical application.
- Quantum optics, investigation of quantum properties of electromagnetic radiation in informatics and cryptography.
- Optics of scattering media, development of methods and devices for investigation and diagnostics of atmosphere and other media, including biological ones.
- Plasma physics, development and creation of plasma technologies and systems for processing and modification of properties of materials and their surfaces.
- Physics of elementary particles and fundamental interactions, nuclear spectroscopy.

The laboratories of the Institute achieved in recent years significant results in the development of scientific and applied problems of these and other directions. Some of them are given in this booklet.

Honored Director of the Institute of Physics of NAS of Belarus
Director of the Institute of Physics from 1985 to 1998 Academician P.A. Apanasevich

Results of the Institute of physics, awarded with State Prizes:

Lenin prize:

Solving of problems of safe movement of spacecrafts in the atmosphere (1966, M.A. Elyashevich together with employees of other organizations)

Creation and development of a new scientific direction - free complex molecules spectroscopy (1980, N.A. Borisevich, V.V. Gruzinsky and V.A. Tolkachev together with B.S. Neporent from SOI)

State prize of the USSR:

Prediction of laser generation of complex molecules solutions and creation of lasers with tunable radiation frequency in a wide range of the spectrum (1972, B I. Stepanov, A.N. Rubinov and V.A. Mostovnikov)

Investigation of radiation scattering in inhomogeneous media and creation of diffraction filters for a wide range of infrared radiation on this basis (1973, N.A. Borisevich and V.G. Vereshchagin)

Development of optics of anisotropic media (1976, F.I. Fedorov)

Development of physical foundations of dynamic holography and light beams spatial structure transformation methods, discovery of the phenomenon of light beams wave front inversion at four-wave interactions (1982, P.A. Apanasevich, E.V. Ivakin, A.S. Rubanov, B.I. Stepanov together with employees of other organizations)

Development of highly efficient methods for nonlinear conversion of laser radiation frequency in crystals (1984, B.V. Bokut together with employees of other organizations)

Investigation of photorefractive and liquid crystals for systems of optical processing of information (1985, V.A. Pilipovich and A.A. Kovalev together with employees of other organizations)

Investigation of photoburning of spectral holes and development of selective spectroscopy of complex molecules (1986, K.N. Solovyov together with employees of other organizations)

Development of optical methods and measuring systems for the parameters of surface objects from airplanes and spacecrafts (1991, L.I. Kiselevsky and B.I. Belyaev together with employees of other organizations)

State prize of the BSSR:

Development of the theory of elastic waves in crystals (1972, F.I. Fedorov)

Development of methods and equipment for plasma investigations in laboratory and natural conditions, including plasma of rocket airfoil at movement in the atmosphere (1974, V.S. Burakov, L.I. Kiselevsky, L.Y. Minko, V.N. Snopko and V.D. Shimanovich)

Development of calculation methods and systematic analysis of the dependence of energy and temporal characteristics of lasers on resonator, active medium, and pumping parameters (1976, B.I. Stepanov, V.P. Gribkovsky, A.S. Rubanov and A.M. Samson)

Development of the theory of the influence of high-power laser radiation on spectral-optical characteristics of a substance (1978, P.A. Apanasevich)

Cycle of works "Photonics of biologically important pigments and their analogues" (1980, G.P. Gurinovich and K.N. Solovyov)

Development of the classical field theory of elementary particles (1988, A.A. Bogush and L.G. Moroz)

Experimental and theoretical investigation of light reflection from amplifying and nonlinear media (1990, B.B. Boyko and N.S. Petrov)

State Prize of the Republic of Belarus:

Investigation of physics of laser-plasma influence to metals and composite materials (1992, M.A. Elyashevich, V.K. Goncharov, L. Y. Minko, G.S. Romanov and A.N. Chumakov)

Development of methods and investigation of protein luminescence with high temporal resolution (1992, L.G. Pikulik together with biologists)

Investigations of microstructure fluctuations and development of photophysics of solutions of complex organic compounds (1994, A.N. Rubinov, B.A. Bushuk and V.I. Tomin together with employees of BSU)

Investigations of anisotropy phenomena in laser systems and development of polarization laser spectroscopy methods (1996, A.P. Voitovich, A.A. Kovalev, V.V. Mashko, V.N. Severikov and V.A. Pilipovich)

Investigations of the dynamics of rotational motion of electron-excited molecules in the gas phase (1998, N.A. Borisevich, V.A. Tolkachev, A.P. Blokhin and V.A. Povedailo)

Investigations of nonlinear-optical phenomena and creation of nonlinear-optical converters of laser radiation wavelengths on this basis (2000, A.A. Afanasiev, V.N. Bely, N.S. Kazak, V.A. Kononov, V.A. Orlovich and T.S. Efendiev)

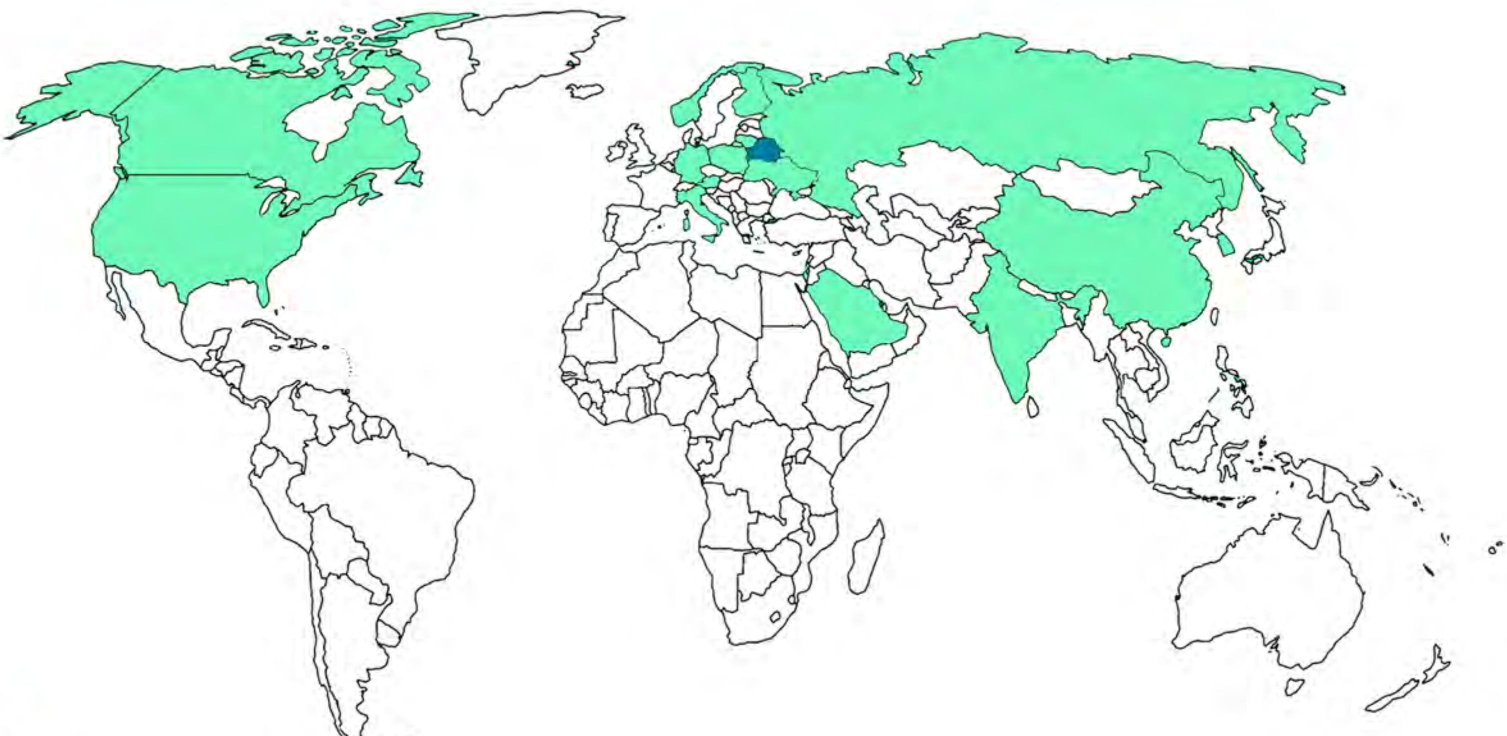
Investigations of mechanisms of photo-damage of eye retina and development of methods for its treatment (2000, G.I. Zheltov and V.A. Lapina together with medics)

Development of quantum optics and spectroscopy of coherent nuclear processes (2002, S.Y. Kilin, E.A. Rudak and A.V. Berestov, together with employees of BSU)

Development and application of lidar and aerospace methods and instruments for diagnostics of the environment (2002, A.P. Ivanov, A.P. Tchaikovsky and V. E. Pluta together with employees of other organizations)

Development and wide implementation of national facilities for protection of documents, funds and highly valued objects based on holographic methods (2012, L. V. Tanin together with employees of other organizations).

Geography of export



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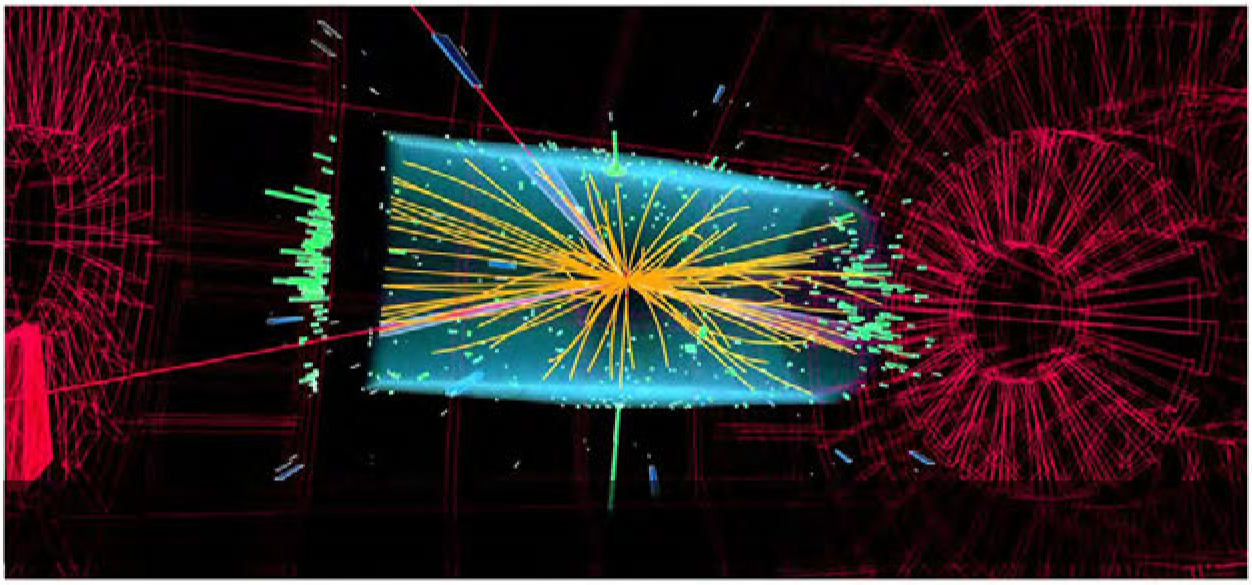
SCIENTIFIC SENTER “FUNDAMENTAL INTERACTIONS AND ASTROPHYSICS”

The main research directions are:

- development of the effective methods of theoretical investigations and their application for solving current problems of astrophysics and physics of fundamental interactions; scientific expertise of complex projects on behalf of higher authorities
- participation in formulation and processing of experimental results in the framework of major international collaborations and projects on searching for new structural elements and phenomena of the space scale, macro- and microworld: ATLAS (Large Hadron Collider (LHC), CERN, Switzerland), COMET (“J-PARC”, Japan), ICRANet (Italy); as well as in cooperation with the astrophysical centers of the National Academies of Sciences of CIS countries (Ukraine, Uzbekistan, Tajikistan)
- conducting fundamental and applied nuclear physics research

Discovery of the Higgs boson at the Large Hadron Collider

Six scientists of the Institute of Physics of NAS of Belarus are the co-authors of the publication on the discovery of the Higgs boson at the Large Hadron Collider (LHC). The leader of the scientific team is the head of the Center Dr.Sci. Yuri Kurochkin.



Observation of a new particle during the search for the Standard Model Higgs boson with the ATLAS detector of the LHC. Phys.Lett. B 716, (2012), p. 1-29.

The result of searching for the Standard Model Higgs boson in proton-proton collisions using ATLAS detector at the LHC has been given. The data sets used correspond to an integral luminosity of approximately 4,8 fb^{-1}, for $\sqrt{s}$ = 7 TeV in 2011 and 5,8 fb^{-1} for $\sqrt{s}$ = 8 TeV in 2012. Individual searches in channels $H \to ZZ(*) \to 4\ell$, $H \to \gamma\gamma$ и $H \to WW(*) \to e\nu\mu\nu$ at 8 TeV are combined with previously published search results $H \to ZZ(*)$, WW(*), and $\tau^+\tau^-$ at 7 TeV and with the results of improved channel analysis $H \to ZZ(*) \to 4\ell$ and $H \to \gamma\gamma$ at 7 TeV. Clear evidence for obtaining a neutral boson with a measured mass of 126,0 ± 0,4 (stat) ± 0,4 (SIS) GeV. This observation having a standard deviation value of 5,9, which corresponds to the probability of the background oscillations of $1{,}7\times10^{-9}$, is compatible with the formation and decay of the Standard Model Higgs boson.

International Collaboration “COMET”

At present, scientists of the Institute of Physics of NAS Belarus are the part of the International collaboration "COMET" (Coherent Muon to Electron Transition) and participate in the experiment on the accelerator “J-PARC” (Japan). The purpose of the experiment is to detect those reactions which are not likely to occur in the Standard Model. Participation in such International collaboration is prestigious for the Institute and the country in general. We are confident that fundamental research of such a level will lead to the development of new technologies in the future.

Superconducting magnets of the channel
for protons transportation to a neutrino target

Japanese complex for proton
accelerators research ("J-PARC" Center)

Discussion of scientific and technical cooperation between Japan and Belarus.
From Japan participated:
Director of “J-PARC” Naohito Saito,
Head of the “COMET” experiment Satoshi Mihara.
(May 28, 2019, Presidium of the National Academy of Sciences of Belarus, Minsk)

Gamma-specrometer

Submersible two-detector gamma-spectrometer based on $SrI_2(Eu)$ scintillation crystals

Purpose:

Gamma-spectrometer is aimed for registration and analysis of gamma-radiation spectra in the geometry of full immersion in water and allows evaluating the activity of isotopes in the water medium in Bq/l.

Component parts of the instrument:

- submersible detector (2 pcs.)
- control unit with mini PC
- deep water cable
- software for storing and processing of spectra

Scintillator type	$SrI_2(Eu)$
Number of detectors	2
Crystal size	Ø 38 mm × 38 mm
Energy resolution along the line 662 keV	3,5 %
Energy range of spectra measurement	from 40 to 3000 keV
Spectrum size measured	4096 channels
Detection limit for ^{137}Cs for 24 h	≤ 0,04 Bq/l
Number of channel in spectrum (selected by the user)	256, 512, 1024, 2048, 4096
Operating temperature	from - 10°C to + 50°C
Maximal operating depth	400 m
Voltage supply	from 9 to 18 V (DC)
Power consumption	≤ 2 W
Network interface	RS-485
Weight	8 kg
Stability: spectral peak shift ^{137}Cs for 24 h	≤ ± 1,0 %
System calibration cycle	≥ 1 year
Identification and quantitative determination of γ-radionuclides in marine water (Bq\l)	^{131}I, ^{134}Cs, ^{137}Cs, ^{60}Co, ^{40}K etc.
Maximal activity measured for ^{137}Cs	> 50 kBq
Measuring error, not more than	from ± 8,0 to ± 10,0 %
Maximal immersion depth for hermetic housings	40 m
Maximal autonomous operation with accumulator	10 days

Prospects:

Works on further improvement of the device in terms of sensitivity and energy resolution increasing are possible.

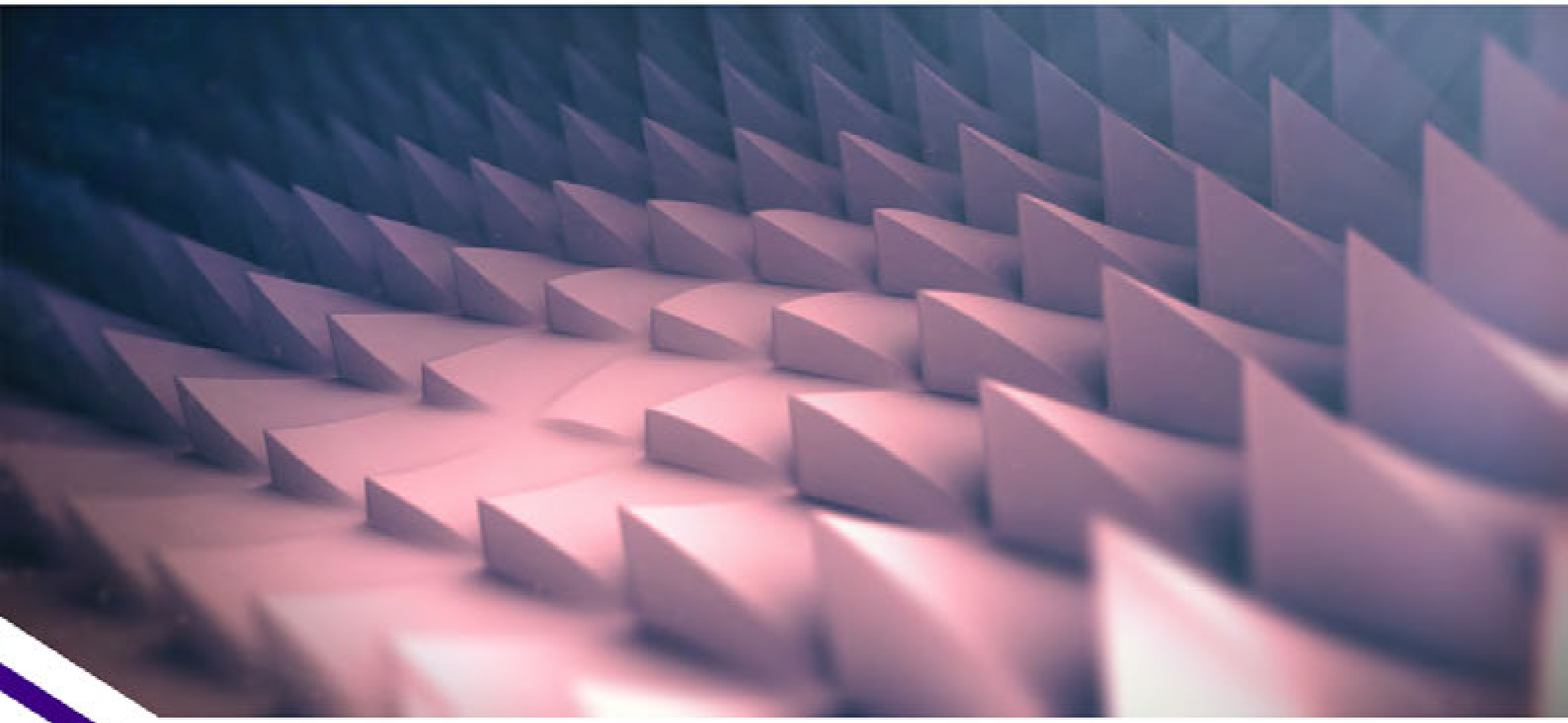
SCIENTIFIC CENTER “DIAGNOSTIC SYSTEMS”

The Center develops modern optical methods and technologies for nondestructive testing and diagnostics in industry and medicine on the basis of multi-channel laser opto-acoustic defectoscopy, multiparameter methods for spectral information analysis, photoacoustic spectroscopy, laser speckle interferometry, microscopy and profilometry based on the use of conical beams; high spatial resolution ellipsometry; polarization-sensitive scatterometry, construction of images in fluorescence decay times (FLIM). The Center conducts investigations on priority directions in the development of security systems based on the control of terahertz images and terahertz spectra.

In the field of laser nanobiology and nanomedicine bionanosensors for early diagnosis of various diseases using plasmon resonance are developed. Based on confocal scanning laser microscopy and femtosecond spectroscopy, new optical methods for diagnostics and treatment of cancer are developed. Unique laser probes and Bessel laser tweezers for manipulation with micro- and nanoparticles have been created.

The main works are devoted to formation, study of properties and application prospects for new types of metal-dielectric nanostructures possessing the properties of optical metamaterials. On the basis of hyperbolic metamaterials new configurations of plane lenses (so-called superlenses) of near and far field have been proposed and implemented.

The properties of laser beams with complex spatial structure (Gaussian, Bessel, conical, Laguerre and Bessel-Gaussian, vortex and singular, quasi-diffractionless speckle fields, Airy beams, etc.) at their propagation and transformation in anisotropic, inhomogeneous and scattering media are investigated in the Center, as well as methods and devices for practical application of these results in mechanical engineering, micro- and optoelectronics.



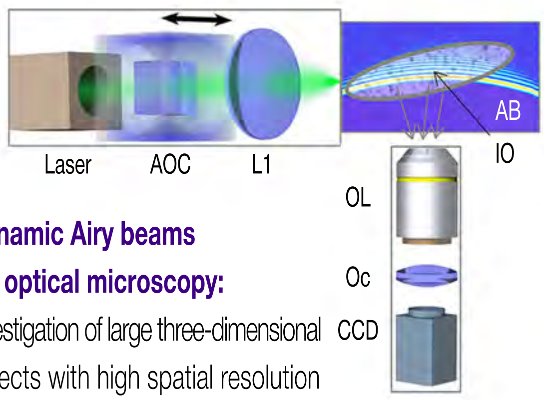
Dynamic Airy beams with high-speed tuning of the curved propagation path

Application:

- optical tomography and microscopy for technical and biological objects probing
- biomedical online-diagnostics based on light sheet microscopy (LS-microscopy). Acousto-optical (AO) tunable LS-microscopy is perspective for the developmental biology, for example, to study the processes of cell division, as well as to study the processes in the nervous system and in the brain
- creating dynamic optical tweezers aimed for moving microparticles along curved paths
- laser processing of materials with curved shape peculiarities
- microelectronics for the formation of non-linear microstructures, for example, in silicon with the use of femtosecond laser Airy beams-pulses

Technical parameters:

- high-speed tuning of movement path with a frequency equal to the frequency of the sound field (from hundreds of thousands to a million Hz)
- ability to control the transverse spatial profile of the dynamic Airy beam, its radius, and a curvature sign
- high-speed cubic modulation of the light beam phase
- combination of high spatial and temporal resolution with increased probing depth



Dynamic Airy beams for optical microscopy: investigation of large three-dimensional objects with high spatial resolution and scanning speed: AOC – acousto-optical cell; L1 – Fourier transformation lens; IO – investigated object; OL, Oc – objective lens and ocular lens of the microscope; CCD – photoreceiving matrix.

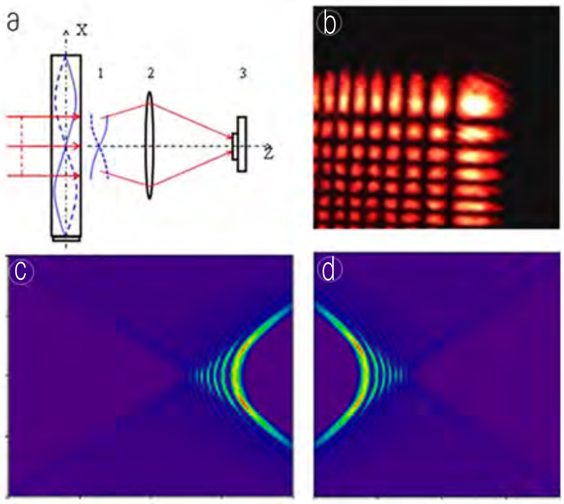


Diagram illustrating the acousto-optical method of dynamic Airy beams (AB) generation (a):

1 – acousto-optical cell

2 – Fourier-transformation lens

3 – CCD- matrix

b – two-dimensional AB; c, d – spatial structures of generated AB with positive (c) and negative (d) curvature.

Features:

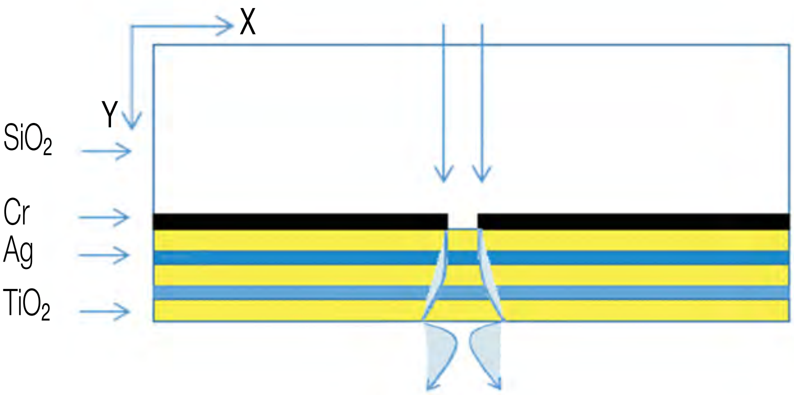
- laser Airy beams are characterized by the energy movement along a curved path and have a property of quasi-diffractionlessness and self-reconstruction of the profile in scattering and inhomogeneous media
- biomedical diagnostics using dynamic Airy beams allows the combination of high spatial and temporal resolution with increased probing depth, which is important for modern research in neuro-biology, as well as for early diagnostics of various diseases
- acousto-optical method of dynamic Airy beams generation

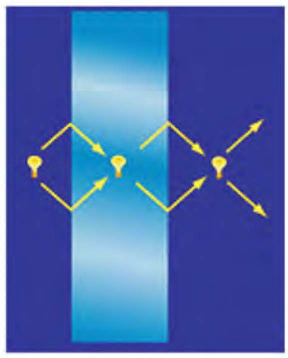
Optical metamaterials

Purpose:

- creation of optoelectronic systems with nano-size elements
- development of nanoelectronics technologies
- tunneling of electromagnetic energy through an ultra-narrow channel
- creation of new optical systems allowing to achieve subwavelength resolution
- development of new sensors with significantly higher sensitivity due to plasmon resonance
- amplification of optical nonlinearities
- formation of narrowly directed light beams

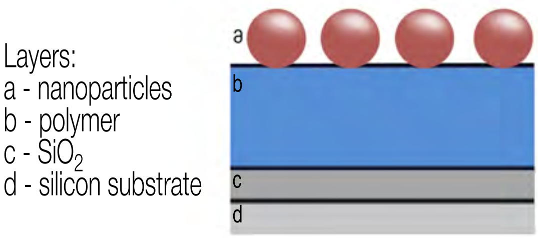
Plane-wave superlens
based on a hyperbolic metamaterial with multilayer metal-dielectric structure



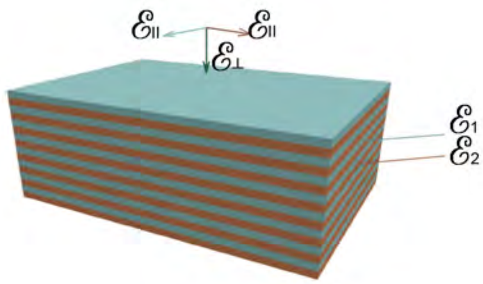


The most prospective areas for creating optical metamaterials

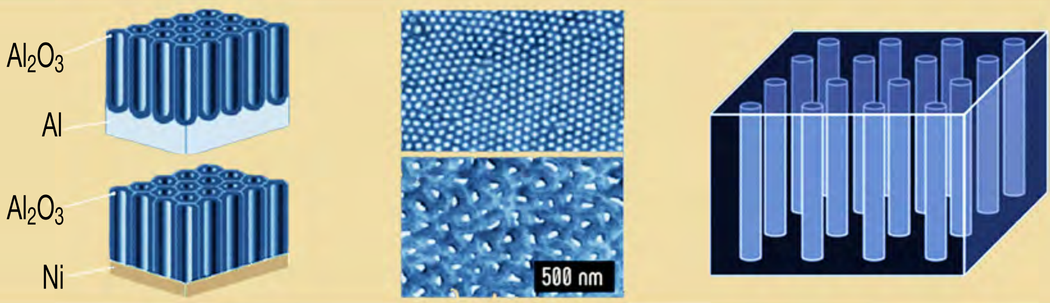
Self-organized structures of metallic nanoparticles



Multilayer metal-dielectric nanostructures



Nanoporous oxide-based metamaterials with nanopores filled with silver

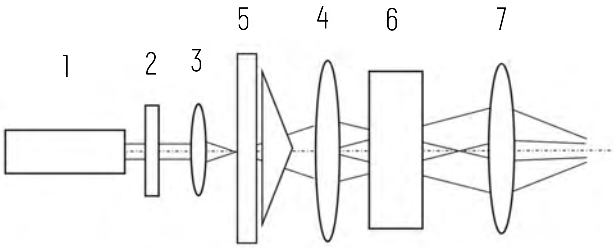


Radially or azimuthally polarized conical light beam generator

Radially or azimuthally polarized conical light beam generator is a system consisting of a linearly-polarized laser radiation source and a unit converting this radiation into radially or azimuthally polarized conical light beam, namely, into Bessel or ring light beam.

The basic optical layout of the device is shown on the figure.

Optical layout of radially or azimuthally polarized conical light beam generator:



1 – laser radiation source
2 – semi-wave plate
3 & 4 – system of spherical lenses forming a telescope
5 – conical lens on the longitudinal carriage
6 – specially oriented biaxial crystal
7 – optional conical or spherical lens

Application:

The device can be manufactured by the order of the interested organizations to obtain radially or azimuthally polarized light beams with the aim to use them in profilometry and precision laser processing of materials. The axial symmetry of the electric vector in the generated light beam allows one to have uniform azimuthal coordinate conditions in terms of the polarization of the incident to the studied surface radiation. Radially polarized laser beam focusing will allow one to form conical light beams with low-diameter intensity maxima due to the longitudinal component of the electric field.

Technical parameters:

- laser radiation wavelength is determined by the wavelength of the laser radiation source used in the generator in the range of 400÷1100 nm
- operation mode is pulsed or continuous, corresponds to the operation mode of the laser radiation source used in the generator
- aperture of the converted laser radiation is 1÷10 mm
- power of the converted laser radiation does not exceed the threshold of the beam strength of the biaxial crystal used in the device with relation to the axial maximum intensity of the output beam inside the crystal
- conversion factor: when using the illumination of the surfaces of the optical elements included in the device - up to 90%, with no illumination - up to 65%

Cross section of radially-polarized Bessel light beam formed with generator

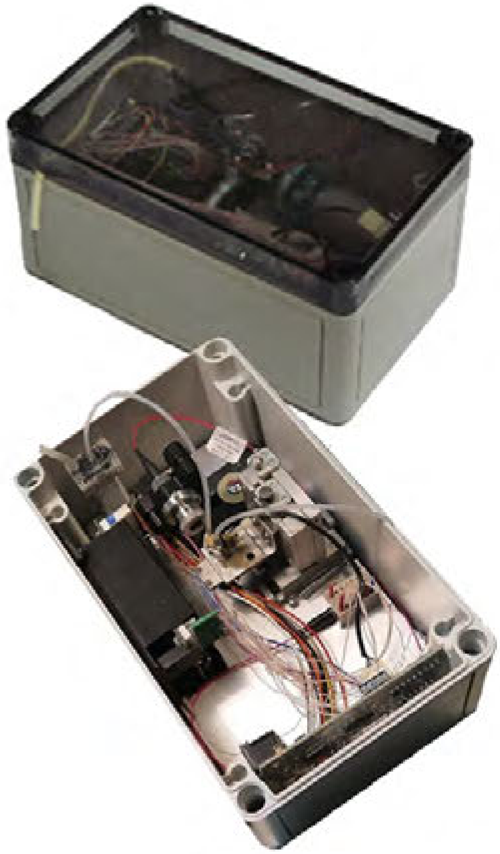
- longitudinal size (length) of the device equals to the sum of the length of the laser radiation source used in the device and the length of the Converter, and is up to 50 cm
- transverse sizes (width and height) of the device are not less than the corresponding dimensions of the laser radiation source

Laser photoacoustic gas analyzer

Gas analyzer based on IR-range diode laser is aimed for local detection of a gas admixture (one gas or vapor of the following liquids: ammonia, methane, ethane, ethylene, acetylene, ethanol, methanol, nitrogen oxide, carbon oxide, carbon dioxide, water). It is suitable for monitoring industrial emissions into the atmosphere, monitoring of technological processes, investigation of human exhaled air and other applications.

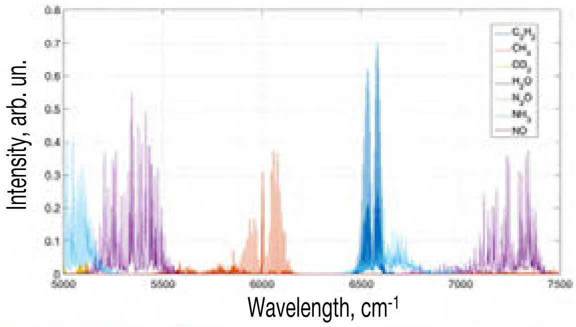
Distinctive features and advantages:

- universality (can be applied to any chemical compound)
- high reliability (as "fingerprints")
- gases identification
- high sensitivity and speed of detection
- compact and simple design



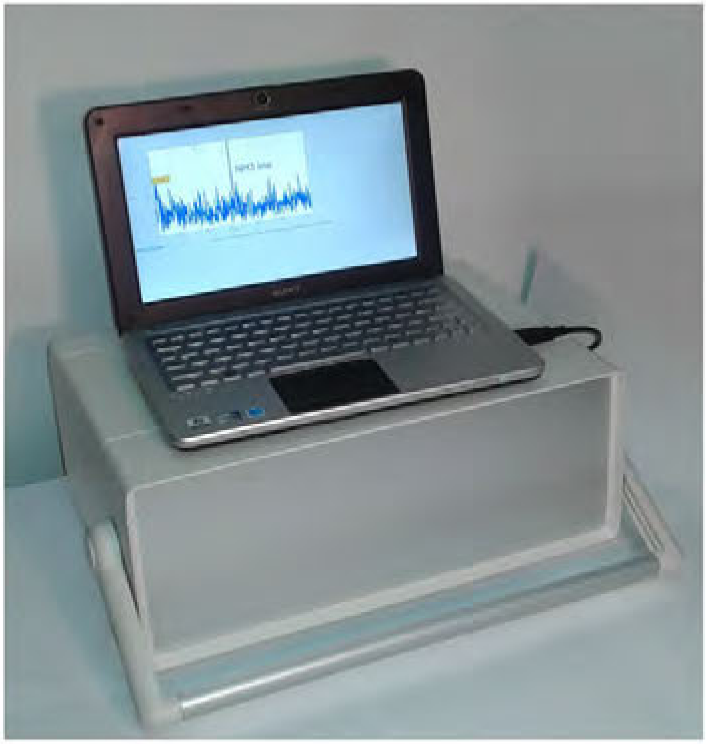
Technical parameters:

- laser type	single-mode semiconductor
- wavelength range	1-2, 4-7 μm
- minimum sample volume	< 1 cm^3
- measurement time	1-2 s
- dimensions	205 × 87 × 65 mm
- weight	< 1 kg
- supply voltage	12 V
- detection sensitivity	absorption coefficient 10^{-7} cm^{-1}



Ammonia detector

The portable autonomous gas analyzer for local online control of the content of ammonia vapors in the air. The operation of the device is based on the method of photoacoustic IR spectroscopy using single-mode laser diode.



Peculiarities:

- autonomy
- portability
- low price

Technical parameters:

- radiation wavelength	1.5 μm
- radiation power	< 5 mW
- battery operation	2 hours
- power supply voltage	5 V
- dimensions	367 × 250 × 143 mm
- measurement time	1-3 s
- sample volume	< 1 cm^3

Application:

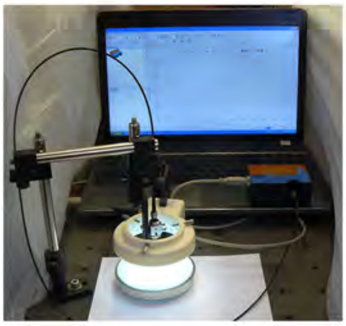
Control of technological processes and monitoring of ammonia losses in various areas of agriculture, food and petrochemical industries.

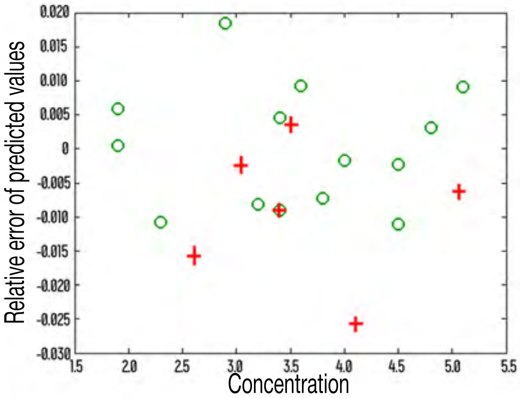
Chemometrics (Identification and characterization of food products properties using multiparametric analysis of optical spectra)

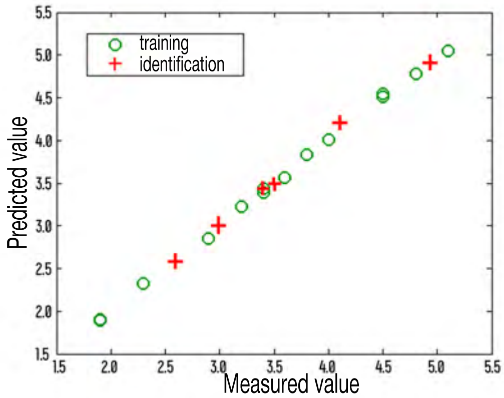
For identification and determination of physical-chemical properties of commercially produced food it is proposed to use optical spectroscopy of UV, visible, and near-infrared ranges with multiparametric methods of data processing. Pilot projects were carried out on the characteristics of vodkas and wines and vegetable oils. The study of 153 sorts of vodka shows the possibility of 100% detection of counterfeit products by using multiparametric analysis of measured in the UV- and visible ranges transmission spectra.

Technical characteristics for determination the characteristics of wines:

- wavelengths range	190–2500 nm (250–750 nm)
- spectral resolution	< 1 nm (2 nm)
- transmission measurement error	< 1%
- identification error	< 5%
- concentration calibration error:	
lilac aldehyde	< 3%
ethyl acetate	< 6%
vanillin	< 16%







The ratio (figure on the right) and relative error (figure on the left) values of the concentration of lilac aldehyde in the training (circles) and identification (crosses) samples of cognac, which were predicted with the projection for latent structures in the transmission spectra in the range of 190-2500 nm.

The developed multiparametric methods for spectral information analysis about similar objects can be adapted for identification and search of counterfeit products also in pharmaceutical, petrochemical, perfume, paints and lacquers, other types of mass production.

Small-size terahertz spectrometer

The terahertz spectrometer is aimed for registration of terahertz transmission, reflection and image spectra, refractive index for solid, liquid and gaseous media, as well as for non-contact detection and diagnostics of properties of semiconductor, ceramic, polymer materials, biological objects and medicines, harmful and dangerous chemical compounds for science, industry, medicine and security systems.

Technical parameters:

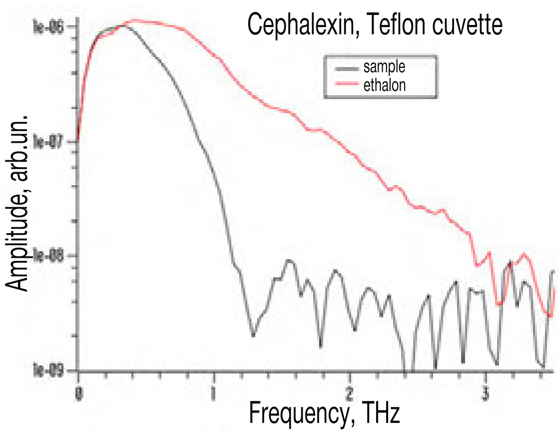
- model	MAK-1
- spectral range	0.2 – 3 THz
- signal-to-noise ratio	60 dB
- temporal resolution	<1 ps
- permissible thickness of the studied object	0 – 10 cm
- excitation laser wavelength	1.03 – 1.06 μm
- duration of excitation pulses	50 – 150 fs
- repetition frequency of excitation pulses	50 – 100 MHz
- average power of excitation laser radiation	20 mW

Peculiarities and advantages:

- simultaneous registration of transmission spectra and refractive index
- possibility of non-destructive testing of properties of objects hidden in paper, cardboard, plastic packaging
- small size and weight

Terahertz radiation from the spectrometer **penetrates through paper, ceramics, leather, clothing, polymers and powder goods.**
Unlike x-ray radiation, it is **not dangerous for human.**

It can be used **in security systems** for detection of drugs, explosives and other substances hidden in paper and plastic bags, under clothing, etc.

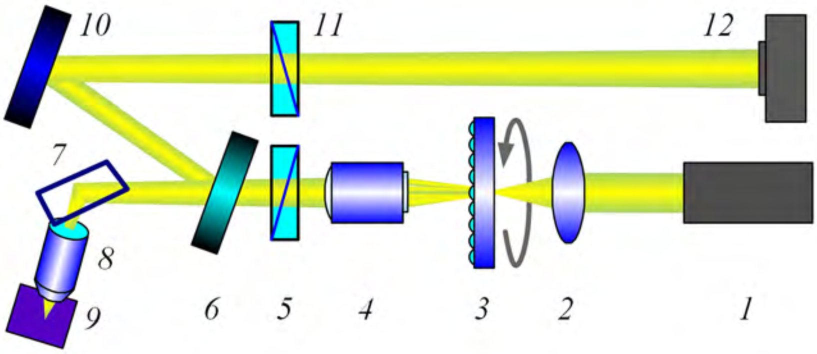





Polarization microscope with laser illumination system

The microscope is designed for the investigation of submicron objects and polarization effects in microbiology and microelectronics.

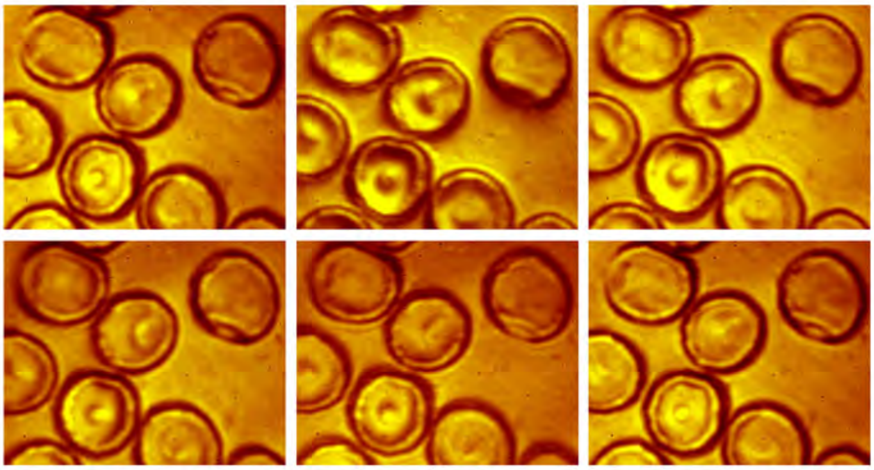
Optical layout of laser polarization microscope with submicron resolution



1 - laser module; 2 - collecting lens; 3 - rotating microlens raster; 4 - condenser; 5 - polarizer;
6 - broadband mirror, R ≈ 50%; 7 - rotary plate; 8 - objective lens; 9 - sample;
10 - broadband mirror, R ≈ 100%; 11 - analyzer; 12 - digital camera without objective lens.

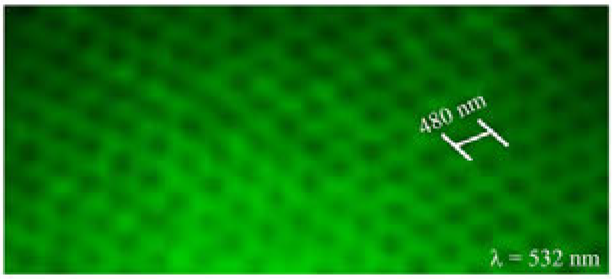
Microbiology:

Dried erythrocytes of human blood under changing oblique illumination (in reflected light). Lens $60^x/0.85$, the wavelength $\lambda = 632.8$ nm.



Sub-wavelength structures:

Microphotoes of structures with a period less than the wavelengths of laser illumination sources. Objective lens $90^x/1.35$, distilled water as an immersion liquid.

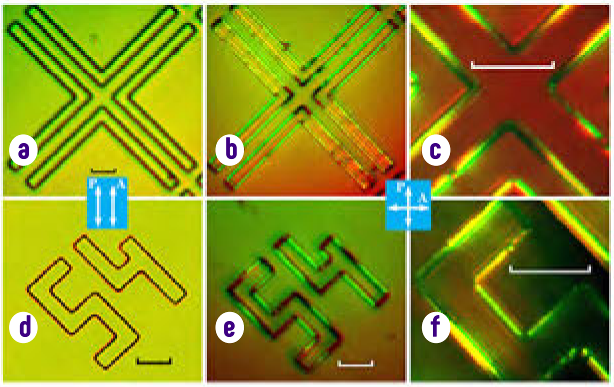


Microelectronics:

Structures on the gold film. The mutual position of polarizer P and analyzer A is shown schematically.

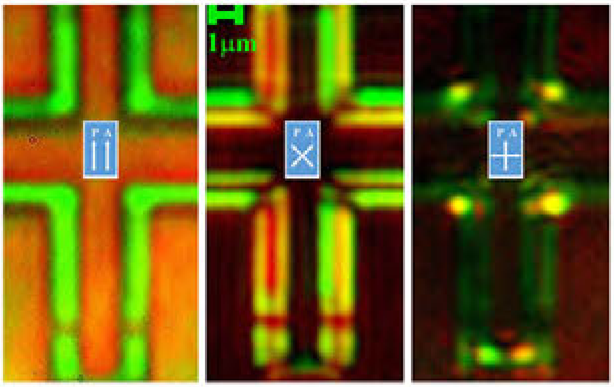
Lenses: $10^x/0.3$ (a, b, d, e) & $60^x/0.85$ (c, f).

Wavelengths: λ_1 = 532 nm, λ_2 = 632.8 nm. Scale of 10 μm.



The components of the chip are rectangular metal structures. Mutual position of polarizer P and analyzer A is shown schematically. Objective lens $60^x/0.85$.

Wavelengths: λ_1 = 532 nm, λ_2 = 632.8 nm.

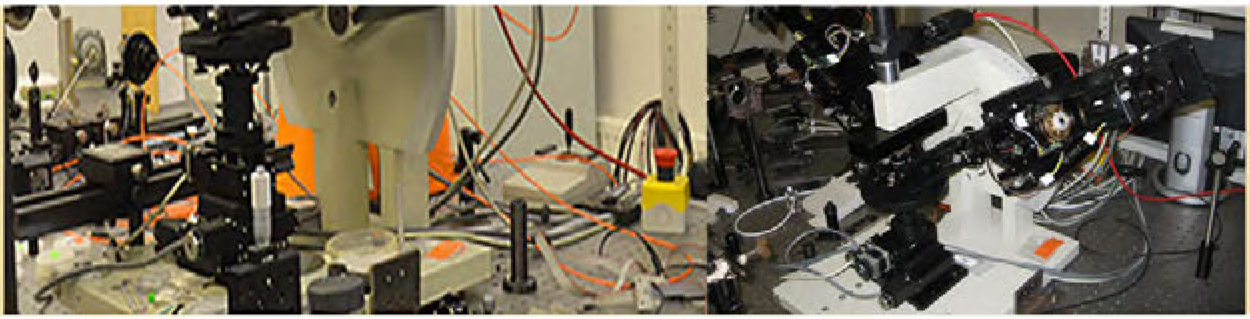


Technical parameters:

The microscope allows registration of the details of birefractive structures with transverse dimensions less than the laser illumination sources wavelength.

Peculiarities of the microscope:

The efficiency of a laser illumination unit with a total power of 20 mW is equivalent to a lamp system with power of > 100 W.



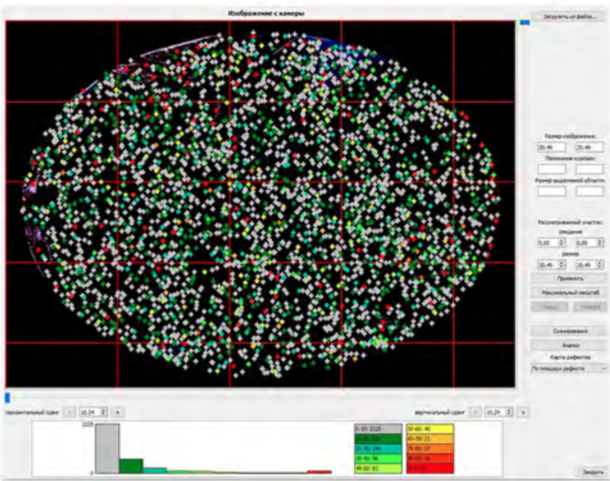
Laser-optical defect analyzer "Luch-54"

Aimed to control the surface of polished wafers made of semiconductor and dielectric materials (silicon, germanium, gallium arsenide, sapphire), including those with epitaxial layer, for the purpose of detection local defects caused by a violation of the crystalline structure (growth defects), odd particles (dust, resist, solvents) and violation of the integrity of technological layers (scratches).

Functions:

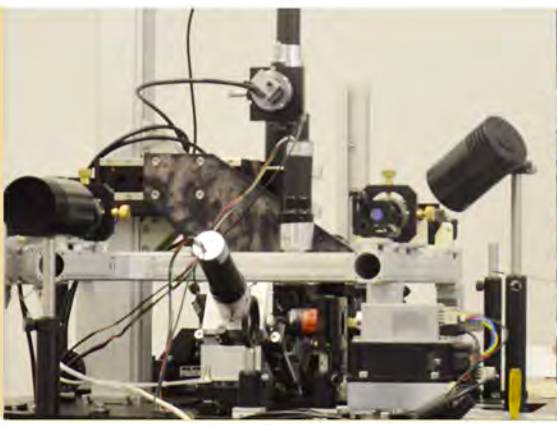
– automatic scanning of the entire plate in high-speed and step-by-step modes
– interactive navigation with a detailed high resolution (up to 200 nm) observation of the plate section
– autofocus
– display in dark and light fields
– display of the plate with various resolution
– automatic recognition of the defect type (growth defect, introduced defect, scratch, contamination)
– automatic calculation of the statistics of defect distribution by size and type
– determination of surface mattness
– automatic saving of measurement results and images to disk or removable data storage

Statistics of defects on the plate



Registered information:

– map of surface defects with defects color coding by size and type
– histogram of particles by size and type
– color-coded surface matte map
– map of the integrated photoluminescence
– images of plate sections with a resolution of 500 (up to 200) nm in dark and light fields



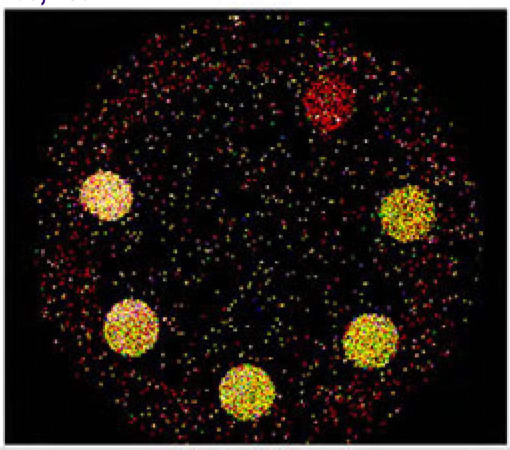
Options:

- polarization contrast (suppression of scattering from the roughness of the surface)
- symmetrical angular laser illumination
- led illumination
- up to four channels of scattered radiations registration
- digital microscope
- removable microlenses, 10^x, 20^x, 50^x
- integrated photoluminescence channel
- loading and unloading of plates - manual mode or from SMIF container

Image of 1 x 1 mm section of patterned plate in light field

Image of 1 x 1 mm section of unpatterned plate in dark field

Image of the test plate (Wafer Calibration Standard, MCP Corp), plate diameter is 200 mm. Observed nanoparticles: 1100, 360, 305, 205, 155, 105 nm

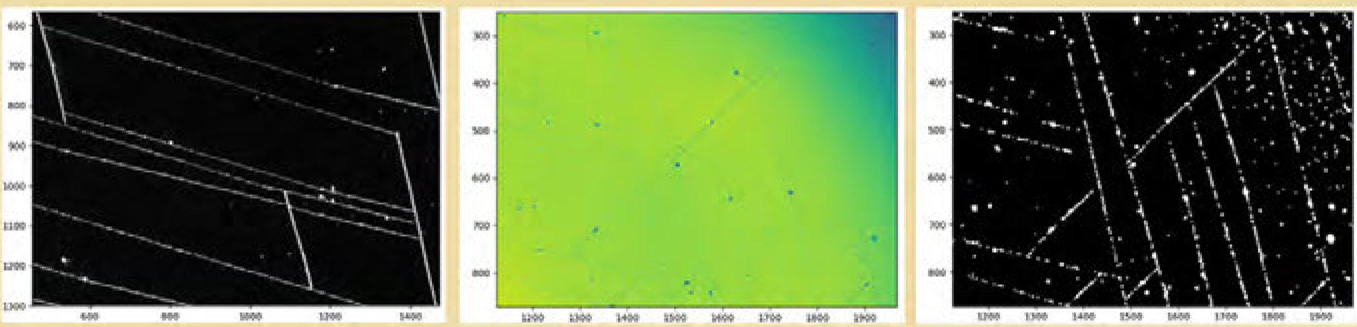


Specifications:

- minimal diameter of controlled defects < 100 nm
- diameter of the controlled plates – up to 200 mm (optionally up to 300 mm)
- min. control time of the plate with diameter of 200 mm – 3 min.
- plate thickness – up to 1000 μm
- type of plates – plates with polished and patterned surface from semiconductor and dielectric materials

Plate matte map, diameter 100 mm

Plates with cracks



Optical coherent tomography setup "OKTEM"

The setup allows non-contact registration of spectral- and polarization-contrast tomographic images of semiconductor and dielectric materials, as well as biological tissues possessing transparency region in IR-range, and evaluation of the morphology and functional state of the object according to these images. It is used for investigations in industrial non-destructive testing and medical diagnostics.

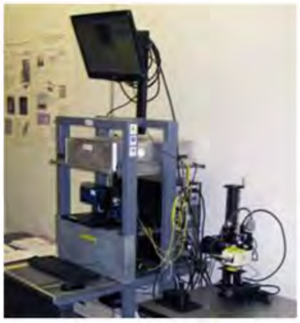
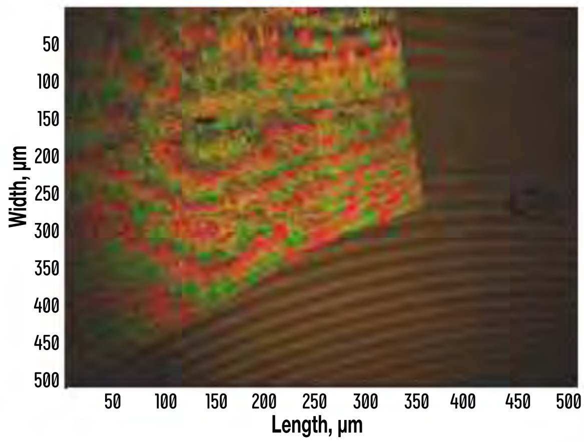
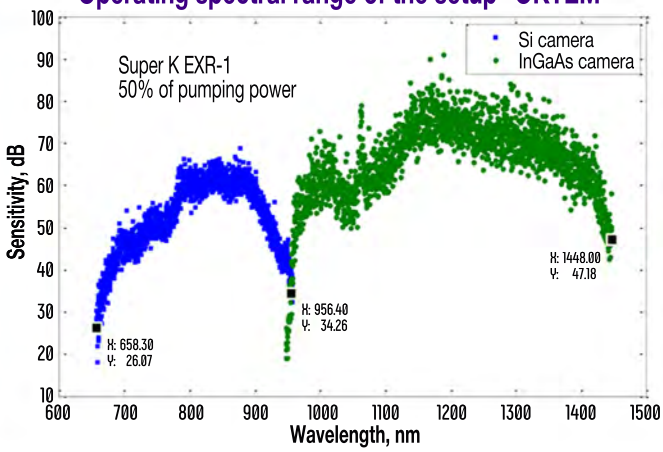


Image of the test structure of anodized Al_2O_3 plate with pores



Operating spectral range of the setup "OKTEM"



Distinctive features and advantages:

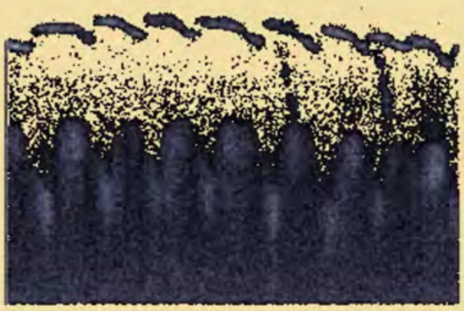
- wide spectral range
- control of the internal structure of materials and products semi-transparent in IR- range
- detection of low-contrast defects
- determination of the morphological properties of the object
- investigations on diagnostics of diseases and degree of invasion of the skin
- development of mobile diagnostic systems

Technical parameters:

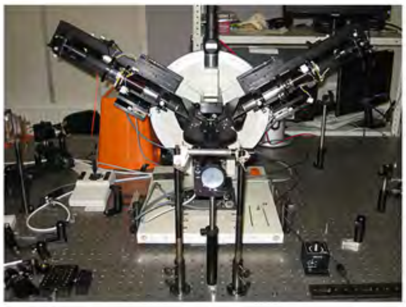
- operating spectral range	650 – 1400 nm
- cross-section resolution	5.5 (up to 1) µm
- longitudinal resolution	< 3 µm (up to 0.6) µm
- scanning area	100 × 100 × 6 mm
- maximal scanning frequency	50 (up to 140) kHz
- contrast	spectral-polarization

The flesh of the apple

The skin of a human finger



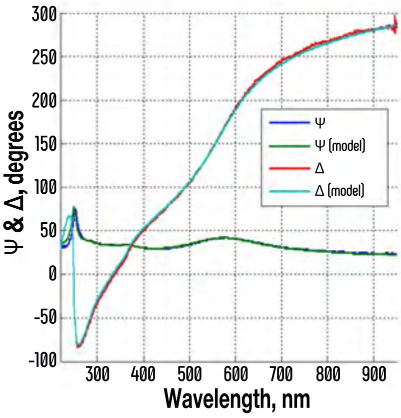
Spectral ellipsometer with achromatic microspot



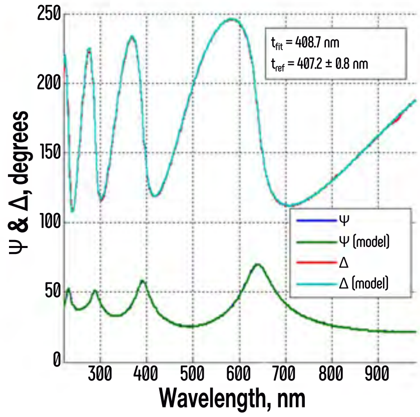
Spectral ellipsometer with achromatic focusing optics allows local measurement of optical parameters of patterned thin films in a wide spectral interval from 220 to 980 nm with cross-sectional resolution of up to 30 μm and film thickness resolution of less than 1 nm.

Experimental and model-calculated spectra of ellipsometric characteristics of film samples:

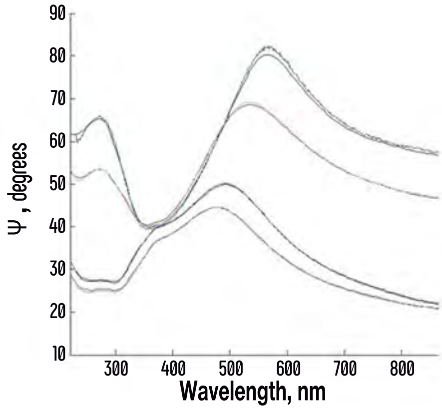
Si_3N_4 on silicon



quartz on silicon



parameters of porous structures of SiO_2/Si, with gold - filled pores

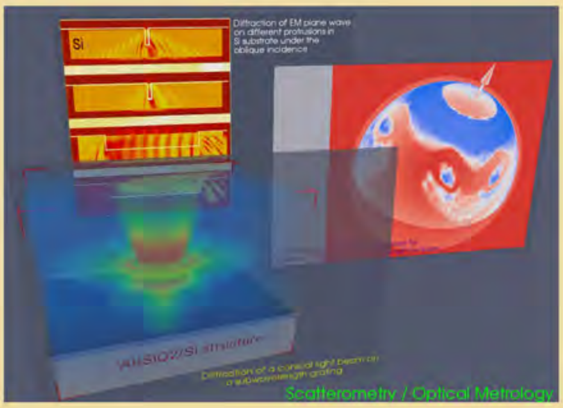


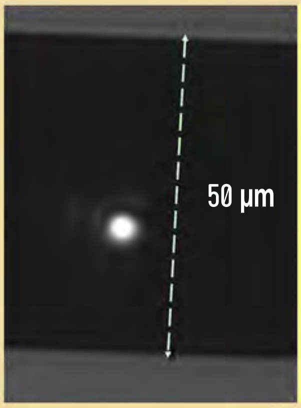
Technical parameters:

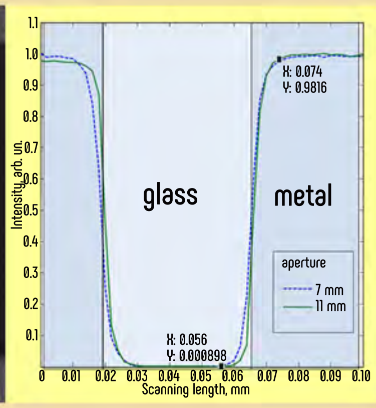
- spectral interval	220 – 980 (190 –1600) nm
- error	± 0.25 deg (on SiO_2/Si samples)
- error	± 0.5 deg (on SiO_2/Si samples)
- layer thickness determination error	± 0.1 nm
- lateral resolution	30 × 50 μm
- range of angles incidence	55 – 75 deg

Peculiarities and advantages:

- not more than 250 characters
- applications for opto- and microelectronics and micro-system technology:
  - determination of dimensional characteristics of volumetric structures and thin films with resolution of less than 1 nm
  - characterization of morphological properties of epitaxial layers and substrates (porosity, surface roughness)



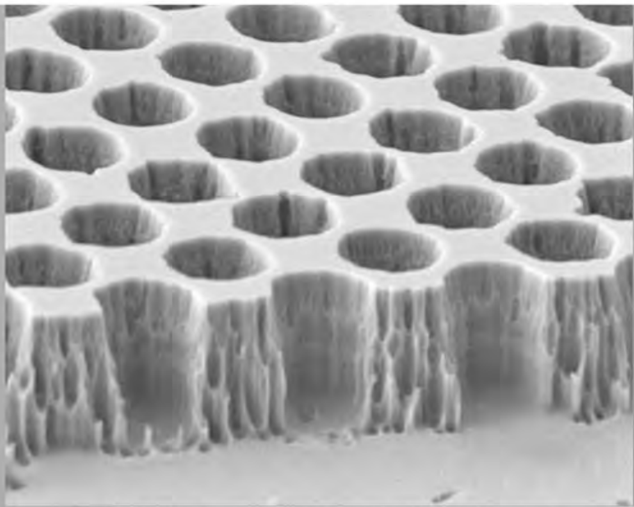


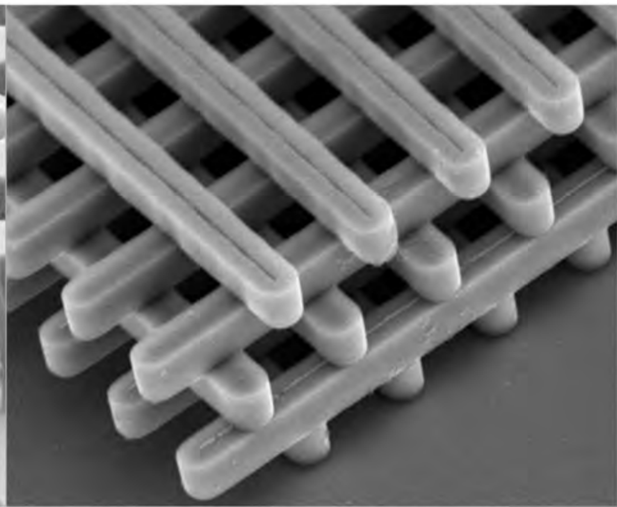


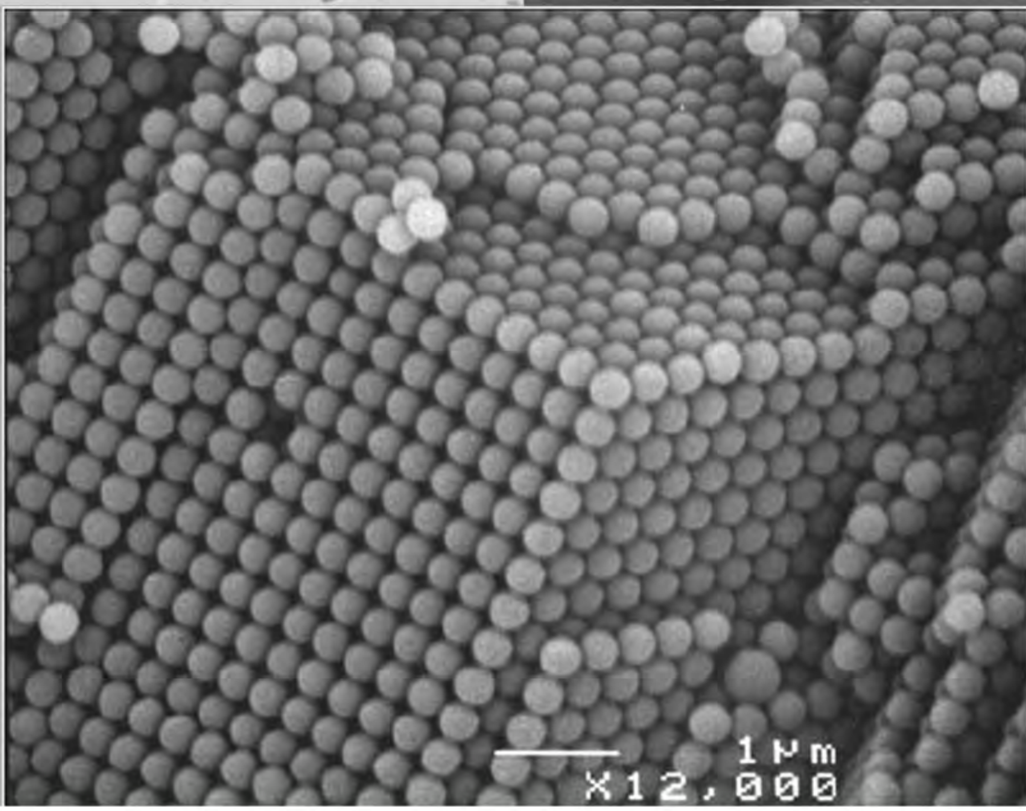
SCIENTIFIC CENTER “PHOTONICS OF ATOMIC & MOLECULAR STRUCTURES”

The main investigation areas are:

- investigation of ultra-fast photoprocesses in a substance based on the development and application of the ultra-short laser pulses method
- optics of randomly inhomogeneous dispersed media, nanostructures and photonic crystals
- spectroscopy and luminescence of high-temperature vapors and jet-cooled molecules
- investigation of radiation defects and their optical properties in crystals and crystalline structures
- development of intellectual decision systems in medicine using computer simulation and Data Mining technology







Pulse-pumped femtosecond laser system

Modern femtosecond lasers are solid-state continuously pumped systems. Femtosecond pulse generators are made on the basis of broadband crystal media (such as titanium: sapphire) or on the basis of optical fiber with specific properties. Light emitting diodes or diode - pumped solid-state lasers are used as pumping sources for femtosecond pulse generators. These generators continuously produce femtosecond pulses with frequency of about 100 MHz. The energy in a single pulse is about 1 nJ. Many practical applications require amplification of these pulses. As a rule, the amplifier is produced on the basis of broadband active media with a pulsed (or quasi-continuous) solid-state laser (for example, Nd:YAG) pumping with a repetition rate of 1 Hz -10 kHz.

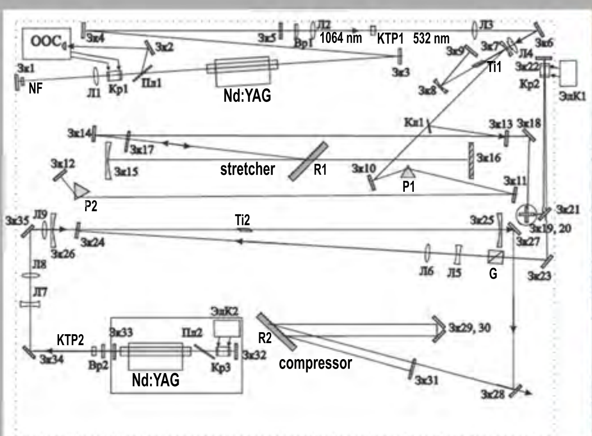
Advantages of such systems:

- high stability of radiation parameters
- high pulse repetition rate

Disadvantages:

- high cost
- low quality of optics
- sensitivity to external effects

The Center implemented a method for using Kerr nonlinearity to synchronize modes in pulsed synchronously-pumped solid-state lasers, allowing one to receive femtosecond pulses, which do not lose their duration to those generated under continuous pumping conditions. Lasers of this type, requiring no expensive pumping systems, and characterized by reduced requirements for the quality of optical elements and compatible with pulsed amplifying cascades are seemed to be quite practical and can find wide application. Due to the original method of femtosecond pulses generation the proposed system can be completely designed on the native element base.



Parameters of a femtosecond laser system:

- pulse repetition rate	up to 50 Hz
- pulse duration	~ 100 fs
- pulse energy	~ 1 mJ
- frequency tuning range	770 - 830 nm

SCIENTIFIC CENTER “QUANTUM OPTICS & QUANTUM INFORMATICS”

Scientific Center "Quantum Optics and Quantum Informatics" was created on the basis of the Laboratory for Quantum Optics – one of the recognized world leaders in the field of quantum optics and quantum informatics.

The growing need for high-speed processing of large amounts of data, as well as the necessity to reduce the technological sizes of micro - and nano - electronics, led to the development of quantum optics and quantum information technologies. Currently used quantum communication (quantum key distribution) technologies, the capabilities of quantum processors and computers being developed, as well as quantum simulators and sensors, raised before science fundamental tasks for developing reliable quantum devices which keep coherence and the property of entanglement, but at the same time allow individual addressing and reading of individual qubits.

The team of the Center has necessary competencies in these rapidly developing directions. They obtained a number of fundamental pioneering results. The theory of detection of quantum states of optical fields, including the theory of continuous quantum measurements; the theory of radiation of single quantum objects; the theory of non-Markov relaxation were developed, and methods for generation of compressed and other non-classical light states were developed.

A number of new quantum effects and phenomena which became the key to the implementation of quantum information technologies were predicted by the employees of the Center. **Among them:**

- effect of grouping and anti-grouping of photons emitted by single emitters (1977). This effect is the basis of the commonly accepted method of testing the "singleness" of quantum systems based on the measurement of $g^{(2)}$
- phenomenon of mono-atomic phase bistability in high-quality microresonators (1991)
- "freezing" of spontaneous destruction in photonic crystals (1992), a phenomenon that is used to preserve the quantum coherence of radiating qubits
- suppression of quantum dynamical tunneling by means of coherent periodic perturbation (1996), a phenomenon that allows one to control the dynamics of qubits, as well as a number of other priority results recognized in the world

A fundamental contribution to the development of solid-state quantum informatics was made: the employees of the Center were the first who proposed the use of solid – state defects- so – called NV centers in a diamond - for quantum information technologies. It was demonstrated that this system ensures the preservation of quantum coherence and entanglement at room temperature, and also provides the opportunity of control over single electron and nuclear spins, that play the role of quantum qubits in various quantum information devices. Applications for quantum systems based on NV-centers in a diamond were developed: from logical quantum gates to quantum sensors (including magnetic gradiometers), which were demonstrated in a number of experiments.

Among other major results of the Center:

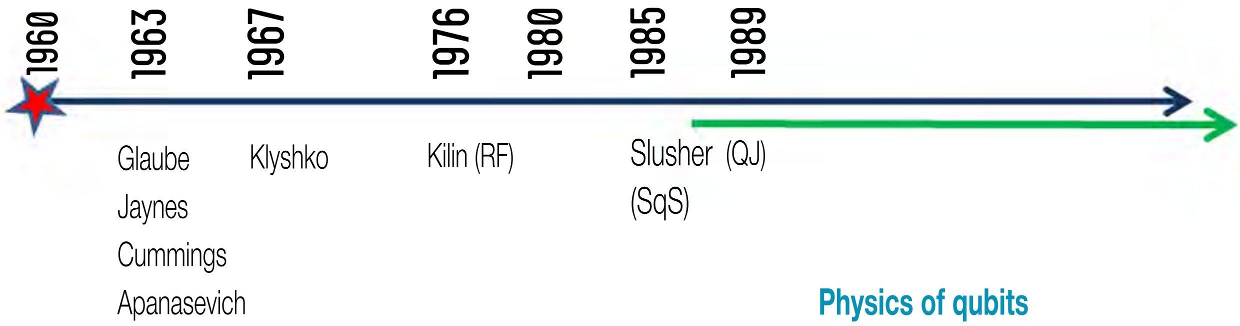
- the first fiber-optic quantum cryptography system in the CIS (2007) based on time encoding of single-photon pulses, providing key distribution over tens of kilometers
- a unique optoelectronic pair - based quantum generator of random numbers that operates on single photons and provides guaranteed quality of random sequences. The generator is used in information security systems (2010).

The laboratory, now the Center, does a lot for the development of quantum optics and informatics in the world and, particularly, in the countries of the former USSR. The first review on quantum informatics in Russian was published in 1999 in journal “Advances in Physical Sciences”.

Were published: monographs on quantum optics (1990, 2001), quantum cryptography (2007) and quantum computing (2010). Famous international conferences on quantum optics and quantum Informatics ICQOQI are held by the staff of the Center every two years. In the 90s, these conferences concentrated Russian scientists and became a catalyst for the development of quantum optics, and then quantum informatics in the CIS. International research projects in the field of quantum physics and informatics funded by NSF (USA), FP6, FP7, Horizon 2020 (EU) and others have been implemented.

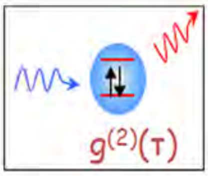
Currently, activity of the Center is focused on the development of quantum measurements theory, solid-state quantum informatics, resonator quantum electrodynamics and quantum-optical neuronets, including:

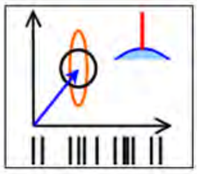
- study and simulation of paramagnetic color centers in diamond and their complexes with nuclear spins for applications in quantum informatics, nanometrology, and nanosensorics
- research on the use of non-classical light states for quantum imaging, sensing, and super-resolution microscopy, quantum diffusion photonics and generation of non-classical light states
- development of quantum theory of time lens and theory of non-classical optical field measure, improvement of quantum cryptography protocols and analysis of their cryptographic stability
- experimental studies of stochastic and nonlinear-dynamic phenomena in vertical-resonator lasers and their use for generation of random numerical sequences and amplification of signals of various types
- studies of up-conversion processes in matrices doped with rare earth ions in application to various spectroscopic tasks
- scanning near-field optical microscopy



Physics of qubits

Photons
flying
qubits

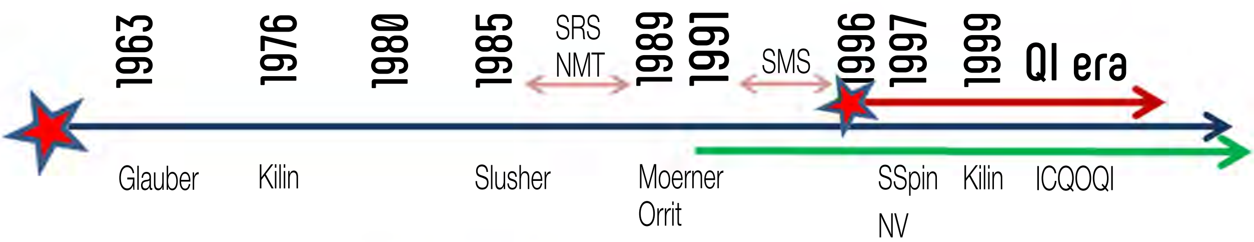




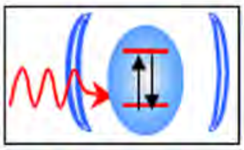
Compressed states – generation, multimode compression criterion, abnormal correlators
Kilin (1985, 1989)
Piskarskas, Stabinis, Gadonas (1990, 1991)

Single-atom resonance fluorescence
Grouping and anti-grouping of photons, collective effects
Apanasevich, Kilin (1976, 1977, 1978, 1979)
Kilin (1980, 1982)

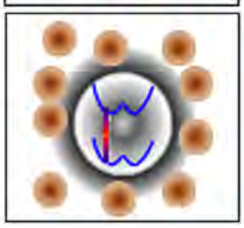
Theory of continuous quantum measurements (quantum jumps)



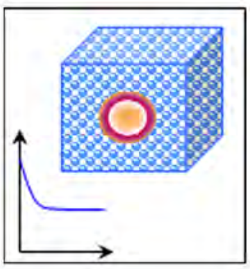
Stationary qubits – single atoms, molecules, color centers

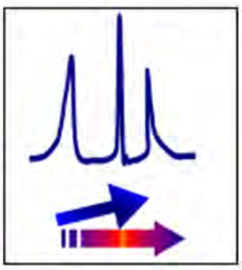


Qubits in the environment – decoherence



Single-atom optical bistability
Kilin, Krinitskaya (1991)
Non-Markov relaxation theory
Apanasevich, Kilin, Nizovtsev (1985, 1987, 1990)
Spectroscopy of single molecules
Kilin, Nizovtsev, Berman, von Borczyskowski. (1996, 1997, 1998)
Suppression of quantum tunneling
Kilin, Berman, Maevskaya (1996)





Freezing of spontaneous decay in photonic crystals
Kilin, Mogilevtsev (1992)
Quantum fluctuations and soliton generation in SRS
Kilin, Orlovich , Grabchikov (1985, 1987, 1992)

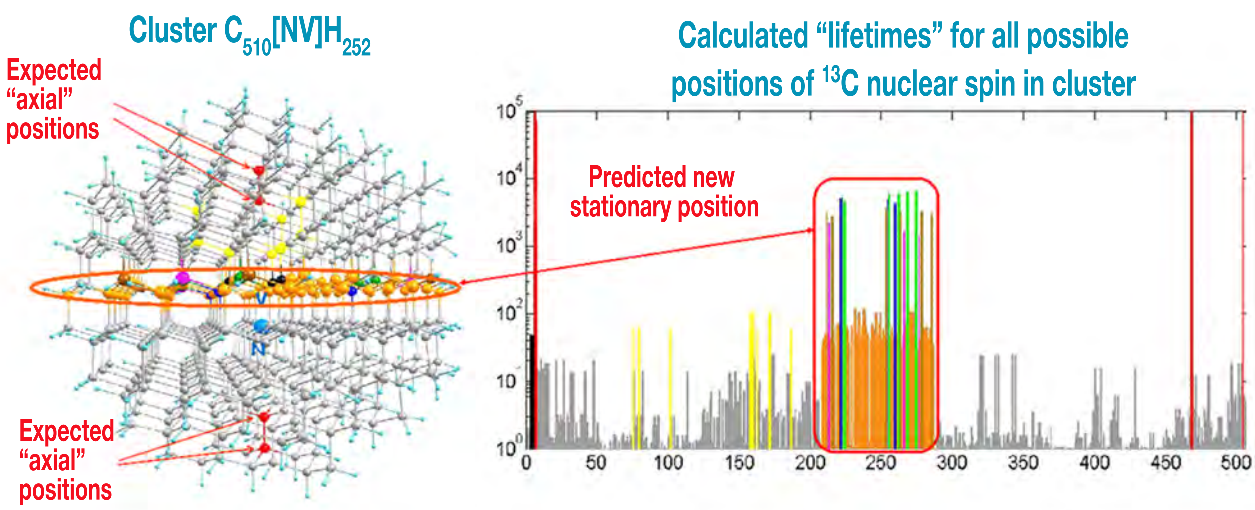
Memory elements of solid-state quantum computers

TOP - 10
NAS of Belarus
2018

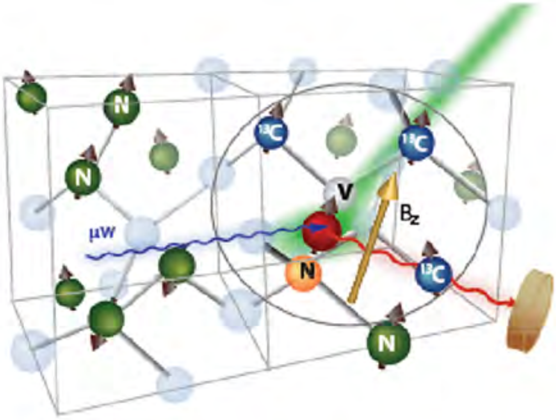
A detailed database on the characteristics of ultrafine interactions of the "nitrogen-vacancy" color center with ^{13}C nuclear spins in nanocluster of a diamond was created for the first time, the existence of a fundamentally new class of stable ^{13}C spins that are most suitable for the use as memory elements of solid-state quantum computers was predicted and confirmed with a target experiment.

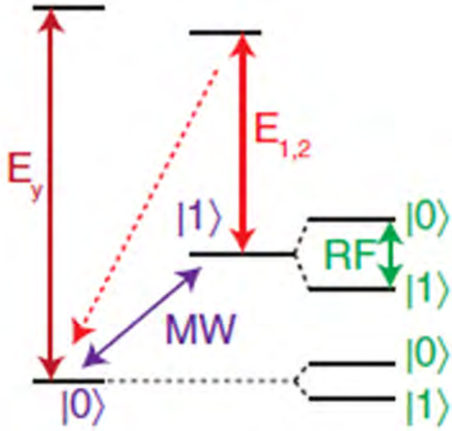
Systems of interacting electronic and nuclear spins in solid bodies are particularly promising for the implementation of the second – generation quantum technologies. In such systems electrons play the role of "fast" qubits and can be used as interfaces with "flying" qubits-photons, and nuclear spins can store quantum information for a long time due to their extremely high isolation from the environment. The most successful representatives of such systems are the "nitrogen – vacancy" [NV] color centers in diamond and their complexes with ^{13}C nuclear spins (natural content ~1.1%). A critical factor for effective implementation of one - and two - qubit operations with the help of such systems is the detailed characterization and complete understanding of superfine interactions (SFI).

On the basis of computer simulation of characteristics of SFI in C_{510} [NV] H_{252} cluster, the experimentally observed values for all possible electron-nuclear spin systems NV-^{13}C, that differ in the position of the nuclear spin ^{13}C in the cluster were calculated. A targeted search was performed for the positions of the ^{13}C atom in the cluster in which the ^{13}C nuclear spin has no stochastic reversals induced by its SFI with the [NV] center electronic spin. In addition to the expected positions of the ^{13}C atom located on the [NV] center axis, the existence of a new class of such stationary NV-^{13}C systems in which the ^{13}C nuclear spin is located in a plane perpendicular to the [NV] center axis was predicted. The predictions made were experimentally confirmed by a special experiment performed in the group of Prof. F. Zhelezko (University of Uhlm, Germany).



“Taming” of separate spins: NV centers in a diamond



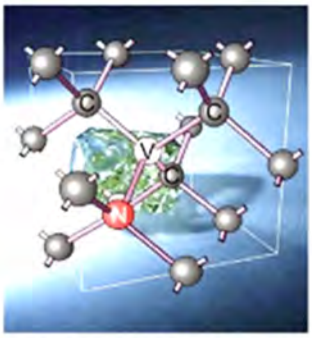


FP 6 IST

STEPANOV INST **Engineered Quantum Information in Nanostructured Diamond**

PHYSICS

University Stuttgart



University of Bristol

QUANTUM PROCESSOR ON NUCLEAR SPINS OF NV CENTRE IN DIAMOND

equind

De Beers

elementsix

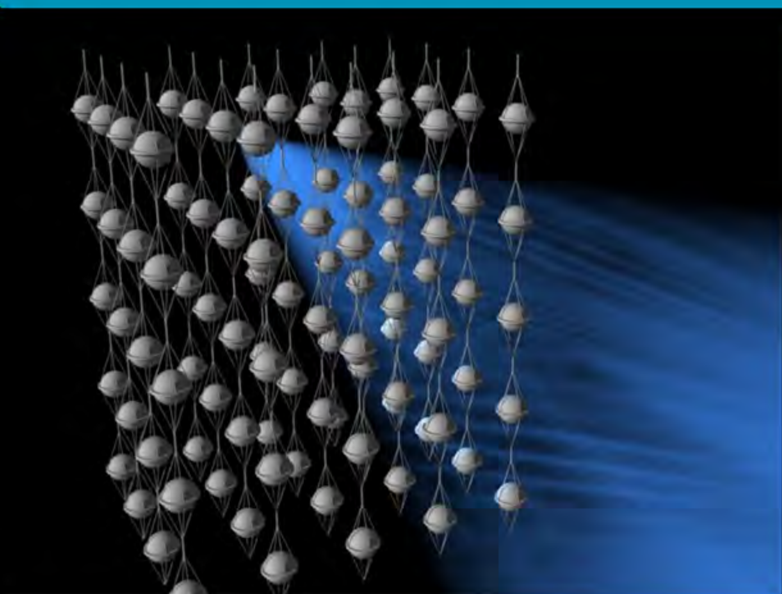
The University of Melbourne

The University of Warwick

Conclusions:

- control over coherently individual nuclear spins (Q physics)
- suppression of spin decoherence (Material science)
- properties of NV+n^{13}C spin system (Q chemistry)

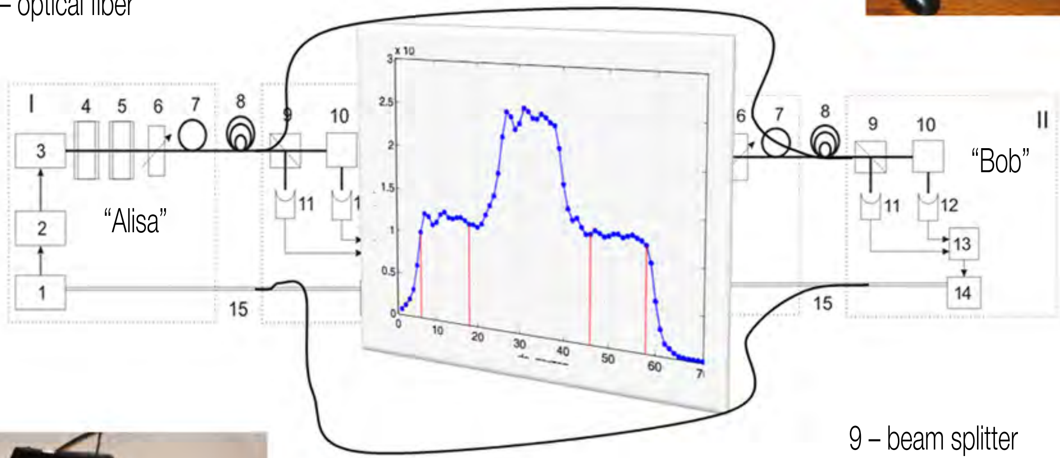
Quantum cryptography on single photons



Quantum cryptography
Ideas and practice, 2007

The first in CIS Quantum key distribution system (QKD) (2007)

1 – PC “Alisa”
2 – TTL pulse generator
3 – semiconductor laser (VCSEL)
4, 5, 6 – attenuators 20, 30 dB
7, 8 – optical fiber

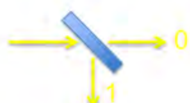


Coding
to time intervals

9 – beam splitter
10 – interferometer
11, 12 – single photons detectors
13 – ADC
14 – PC “Bob”
15 – classic connection channel

Quantum random number generators

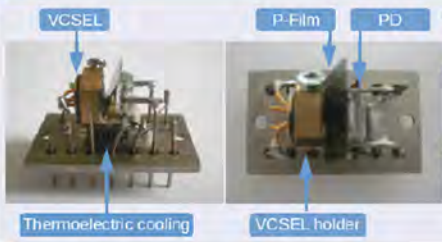
Single-photon RNG



Randomness of reading times

Built-in version

Entropy source



- VCSEL laser 850 nm
- Polarization film 850 nm
- Detector 10 ns, 2.75×2.75 mm^2

Specification

- Data output Ethernet 1Gbit
- Speed: up to 600Mbit
- Power supply: ~220V
- Dimensions: 20cm×25cm×5cm
- FPLD Altera Cyclone IV

Test batteries

- ENT-tests (http://www.fourmilab.ch/random)
- NIST (NIST Special publication 800-22 Revision 1, 2008)
- DieHard (http://www.csis.hku.hk/~diehard/)

Result

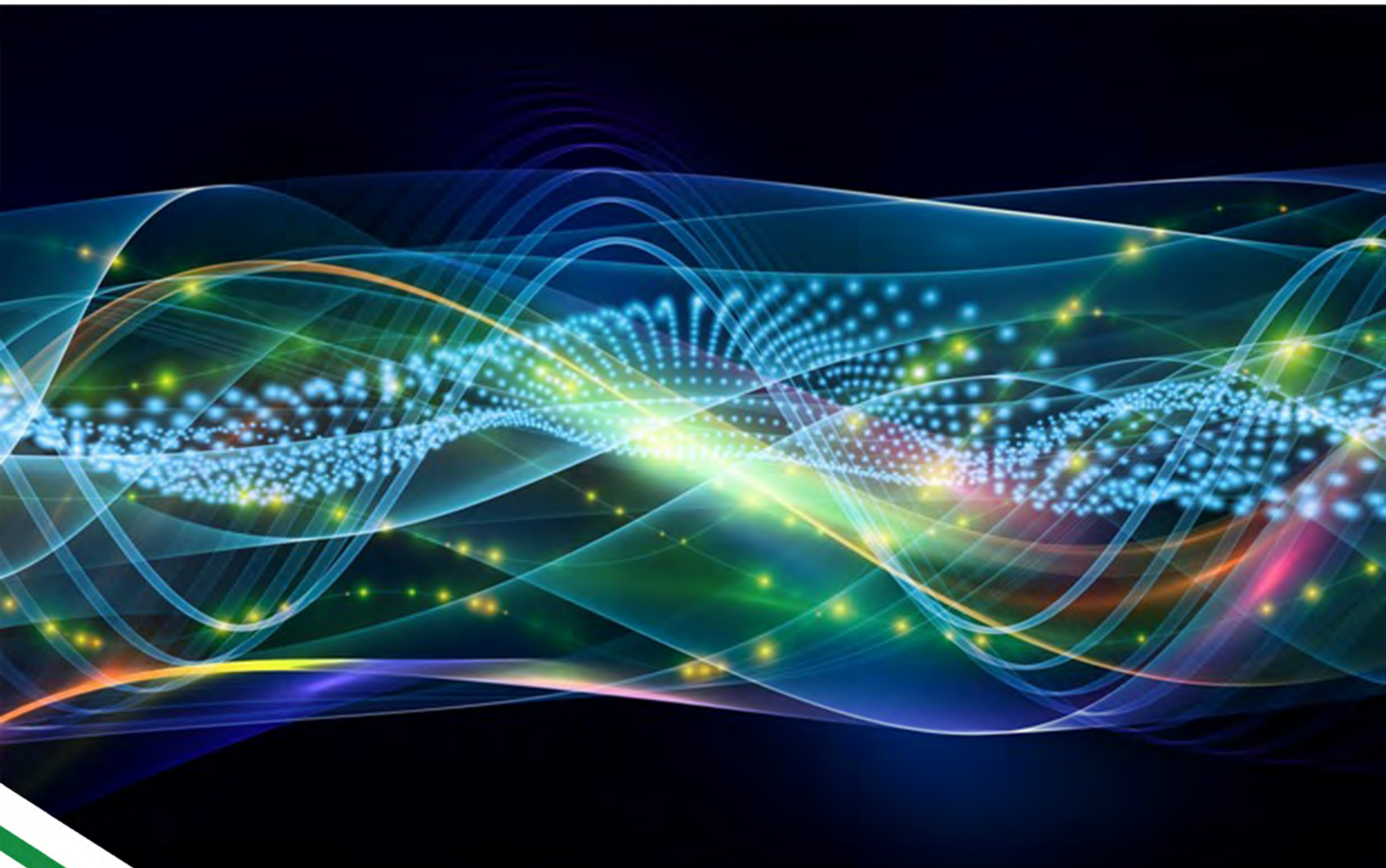
All tests are successful

SCIENTIFIC CENTER “NANOPHOTONICS”

The center is a leader of the Republic in the field of nanophotonics – one of the most actively developing directions of modern physics. The research carried out covers a wide range of issues related to the interaction of electromagnetic radiation with matter in nanoscales, fundamental theoretical and experimental studies of the optical properties of complex structures including disordered systems, photonic crystals and metamaterials are performed.

In particular, the team of the Center has shown that plasmon nanostructures can be applied for luminescence enhancement, detection of refractive index changes, surface-enhanced Raman scattering spectroscopy, which can later be used to create nanosensors and light-emitting elements, medical and photovoltaic applications, and for the analysis of works of art.

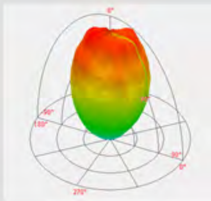
To solve these tasks, a number of methods for synthesis of nanostructures of complex topology and original approaches have been developed. Considerable attention is paid to the instrumentation, particularly, an original measuring complex – goniophotospectrometer "Globoflux" for measuring the spatial characteristics of the radiation of luminescent structures and LEDs was developed and designed in the Center.



GONIOPHOTOSPECTROMETER

Application area:

- measurement of the angular distribution of radiation parameters of LEDs and luminescent structures with external excitation
- measurement of scattering diagrams



Technical parameters:

- scanning range	
in tangential direction	0 – 90°
in radial direction	0 – 360°
- angular resolution	0.5° or higher
- positioning accuracy	0.6
- minimal source brightness	10 mcd
- distance between source and receiver *	150 – 700 mm
- weight*	50 kg
- overall dimensions*	1500 × 500 × 300 mm^3

* Can be changed according to customer requirements

Measured values:

- spectral density of energy illumination ($W/cm^2 \times nm$)
- light flux (lumens)
- correlated color temperature (K)
- color coordinates (CIE x, y; u′,v′)

Advantages:

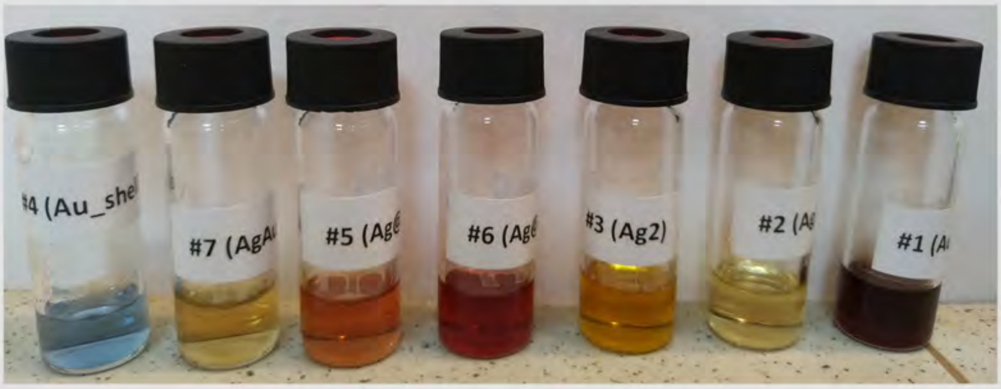
- registration of radiation parameters in the entire front hemisphere of the investigated source
- fully automated measurement process
- opportunity of studying the polarization characteristics of radiation sources
- tuning the equipment, measuring parameters and results processing in one program
- opportunity of export of measured data for further processing in standard mathematical programs

The complex provides full automation of measurements and representation of results in the form of three-dimensional diagrams in the selected measurement units, as well as in the form of sections depending on the angle and wavelength.

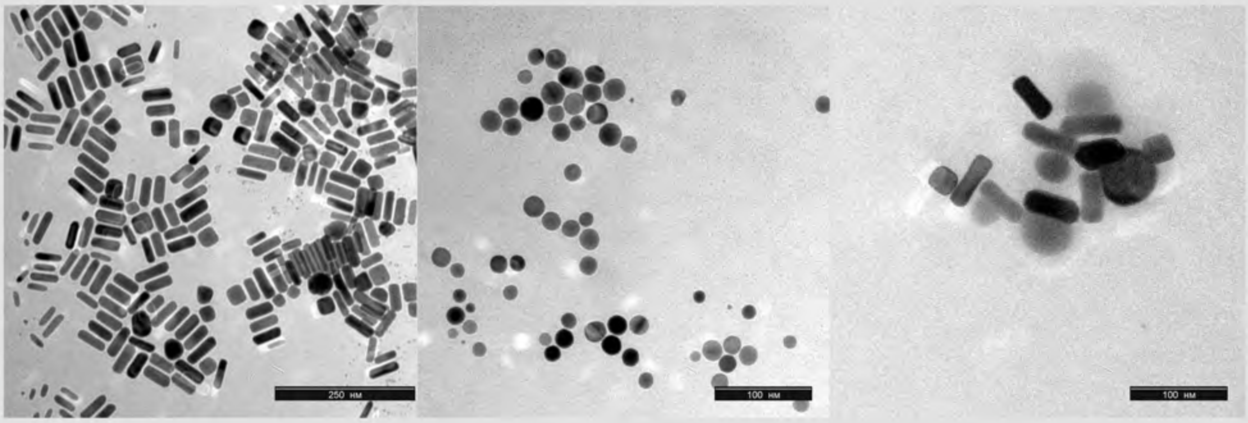
Plasmon nanostructures

Due to the unique properties, metal nanoparticles are widely used in various fields of science and technology (catalysis, optoelectronics, medicine, etc.). They can act as nanoantennas amplifying the external electromagnetic field and affecting the radiative properties of nearby molecules or quantum points. This opens up wide opportunities for the control over the optical properties of materials by choosing the size, shape and spatial organization of the metal nanoparticles which are in contact with them. In the Scientific Center "Nanophotonics" methods for the synthesis of gold and silver of various morphology in aqueous and non-aqueous solutions were developed, including nanoparticles of "core-shell" type and films based on them.

Examples of gold and silver nanoparticles produced in the Center:



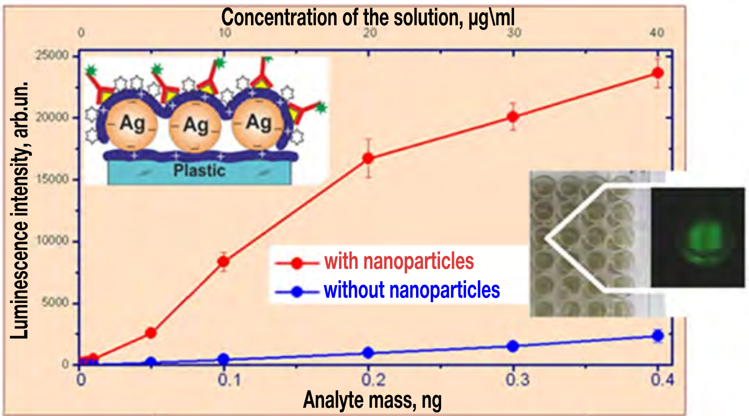
Nanoparticles and metals films obtained in the Center **are successfully applied to implement the plasmon amplification of Raman light scattering.** This effect is used to detect ultra-small amounts of a substance, including the determination of the composition of paint layers of works of art and detection of toxic substances in water. In particular, the team of the Center proposed a new approach for determining the concentration of bromate - anions in water, which is 1-2 orders more sensitive compared to other methods and does not require any expensive equipment. The effectiveness of colloid silver films



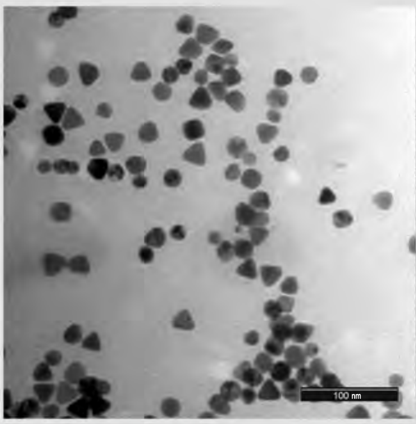
the method of obtaining of which was developed at the Center, as effective sensor substrates used to enhance the Raman scattering signal at monitoring the reaction between bromate anions and dye molecules was demonstrated experimentally. The developed method can become a basis for inexpensive bromate-anion sensors, this is especially important for the analysis of composition of drinking water obtained by desalination.

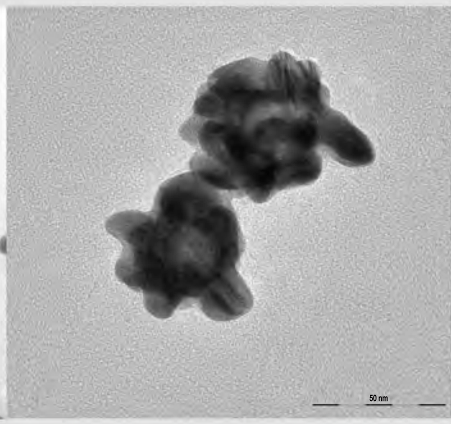
Metal nanoparticles are used **to improve the characteristics of light-emitting structures,** such as LEDs or sensors based on luminescent materials. Particularly, a laboratory method for obtaining nanotextured metallized substrates **to increase the sensitivity of fluorescence detection of marked human antibodies** has been developed. A distinctive feature of the method is the use of a functionalized polymer surface to create a close packing for metal nanoparticles on the surface. The method was tested for antibodies to alpha-fetoprotein and prostate-specific antigen. The results are important for the development of compact sensors for detection cancer markers in human blood and other human bioliquids for the early diagnosis of cancer diseases.

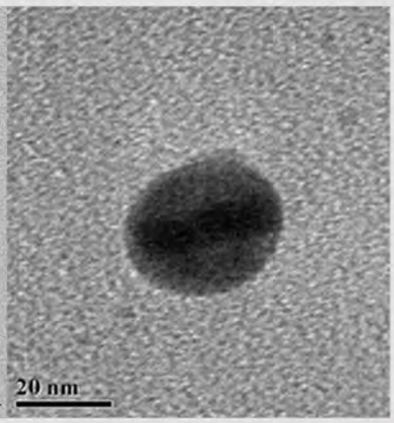
Dependence of the fluorescence intensity on the number of antibodies to the prostate-specific antigen without silver nanoparticles and with nanoparticles:



Intensification factor – 10 -18 times



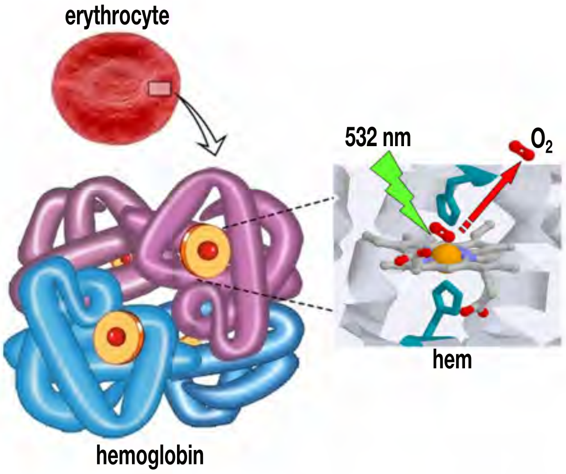


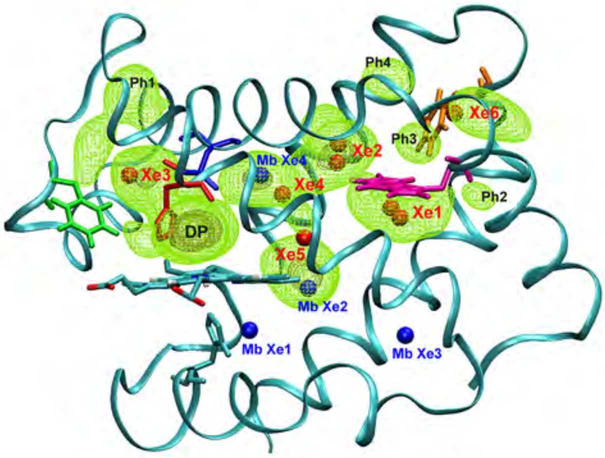


SCIENTIFIC CENTER "PHOTONICS & PHOTOCHEMISTRY OF MOLECULES"

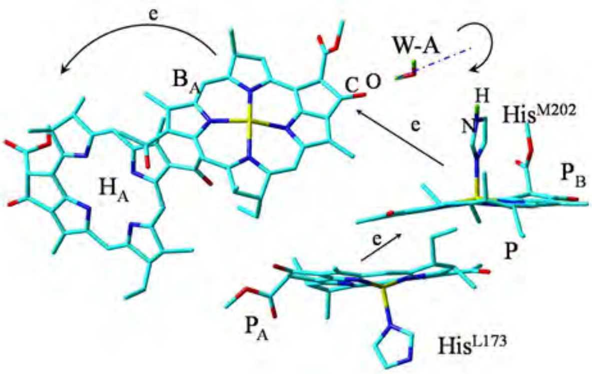
Scientific directions:

- establishment of links between structure, function and dynamics of hemproteins with the methods of time-resolved spectroscopy, quantum mechanics and molecular dynamics

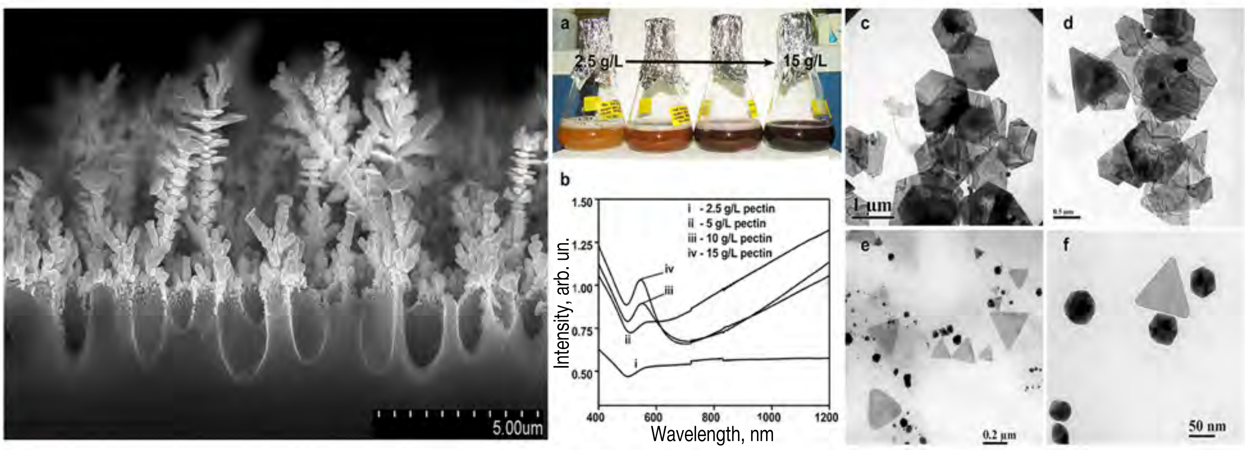




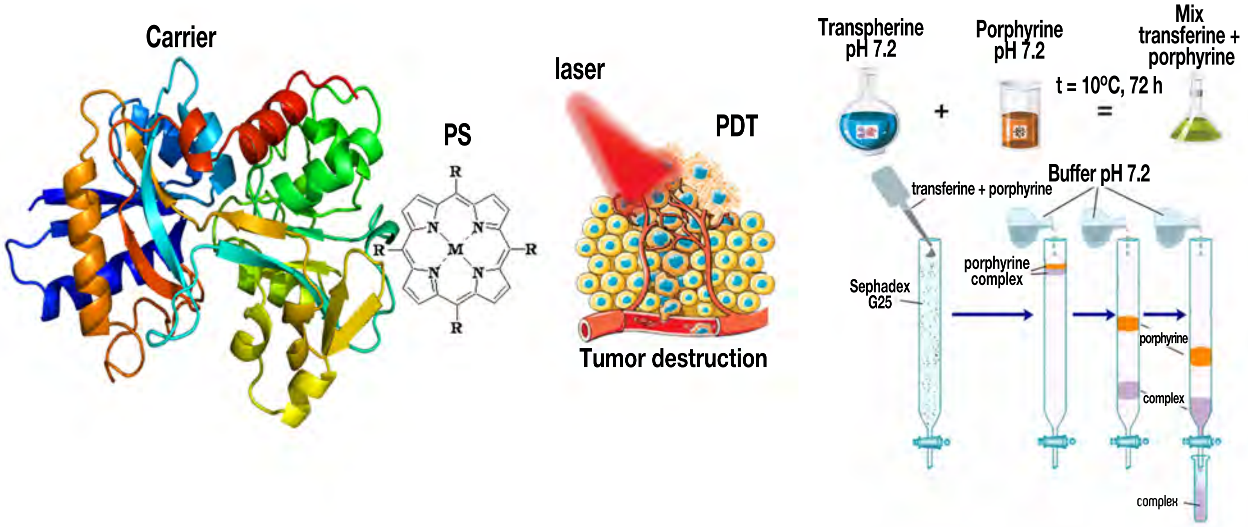
- investigation of spectroscopic and physical-chemical properties of tetrapyrrole molecules with quantum chemistry methods, revealing the detailed mechanisms of photochemical processes in natural and artificial complex molecular systems



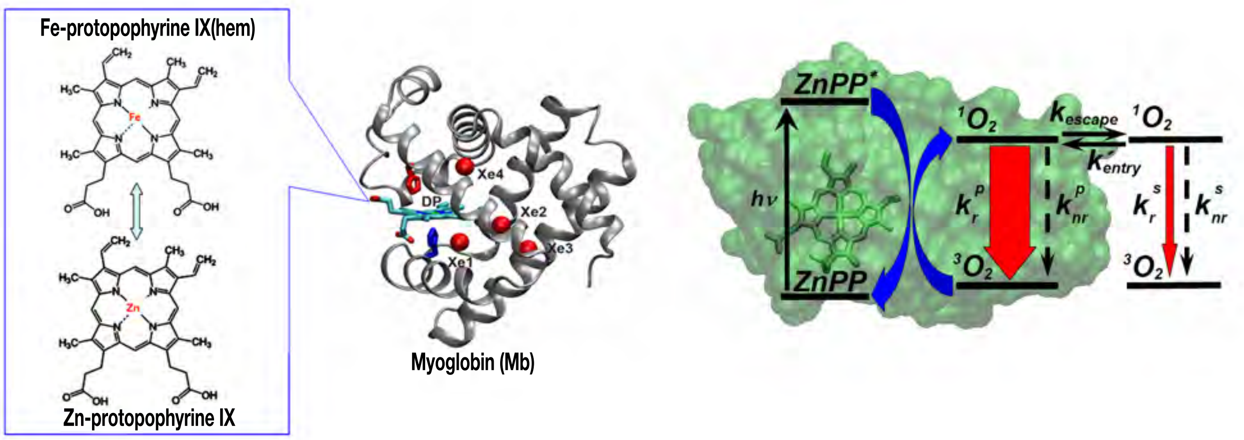
- development and optimization of methods for formation of plasmon nanostructures that are promising for the use as active components of biomedical and analytical sensors based on the surface-enhanced Raman scattering effect



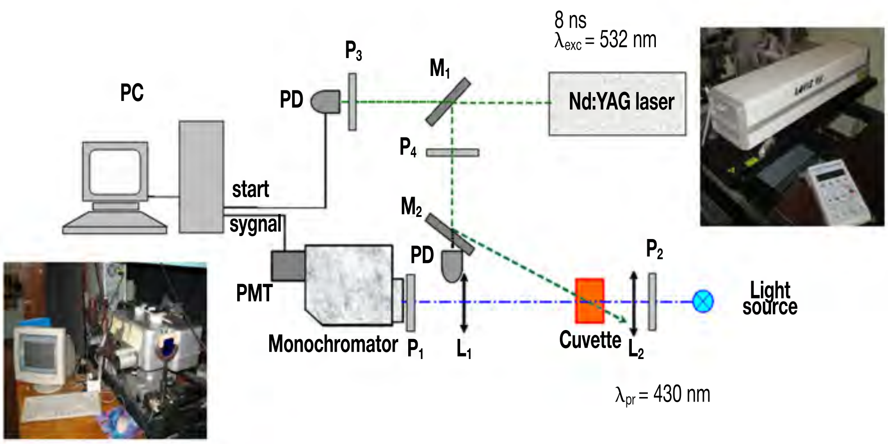
- investigation of complexes of tetrapyrrole compounds with various delivery systems in order to create a new generation of photosensitizers (PS) for photodynamic therapy (PDT) of oncological diseases



- investigation of mechanisms and dynamics of reactions of singlet and other reactive oxygen forms in model biological systems



- laser kinetic absorption spectroscopy of biological objects with nanosecond temporal resolution

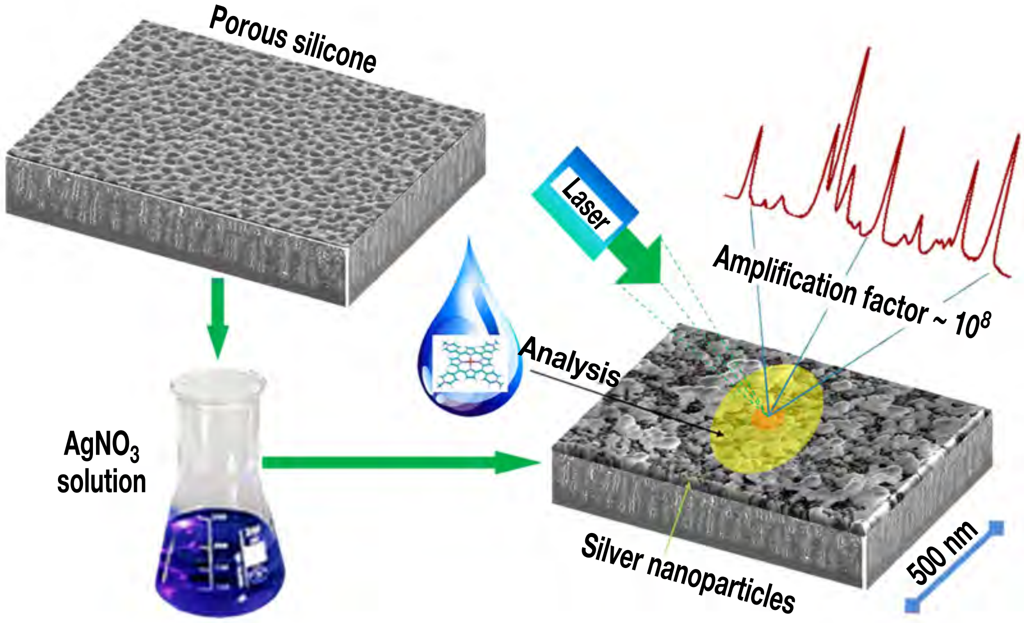


SERS-active substrates

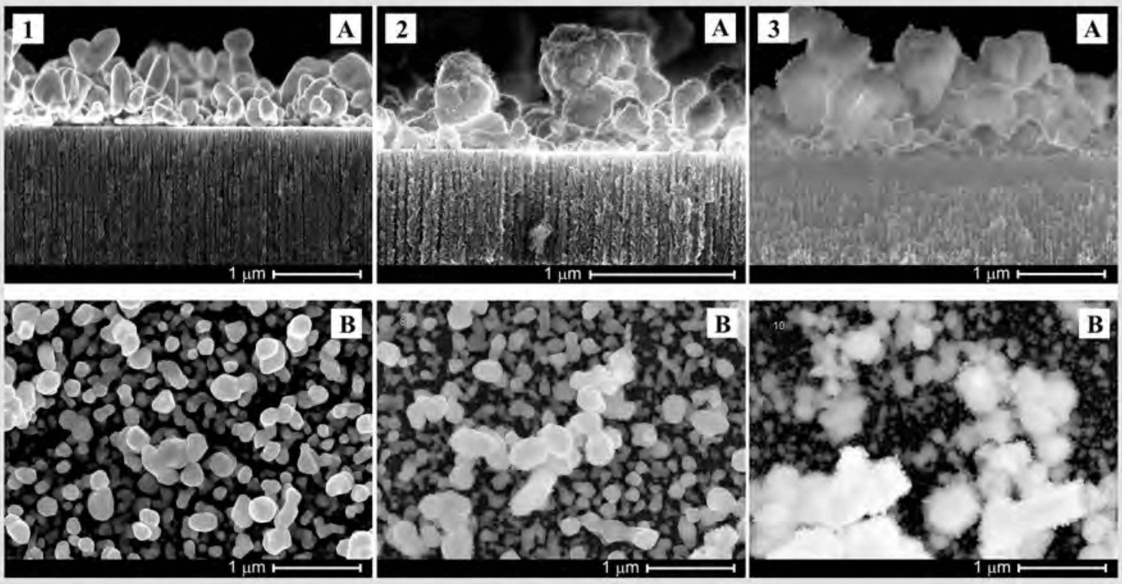
A method of immersive deposition of silver on the surface of porous silicon for application as active substrates for surface-enhanced Raman spectroscopy (SERS)

The main characteristics of the SERS-active substrates:

- SERS amplification factor	2×10^8
- 6G rhodamine detection limit	~10 pM
- uniformity - deviation of SERS signal over the surface	less than 10%
- remain sensitive when stored for a month	



Formation of silver nanostructures on the surface of porous silicon



Porous layer thickness: 1 – 5 µm, 2 – 10 µm, 3 – 20 µm. A – cross - section, B – top view.

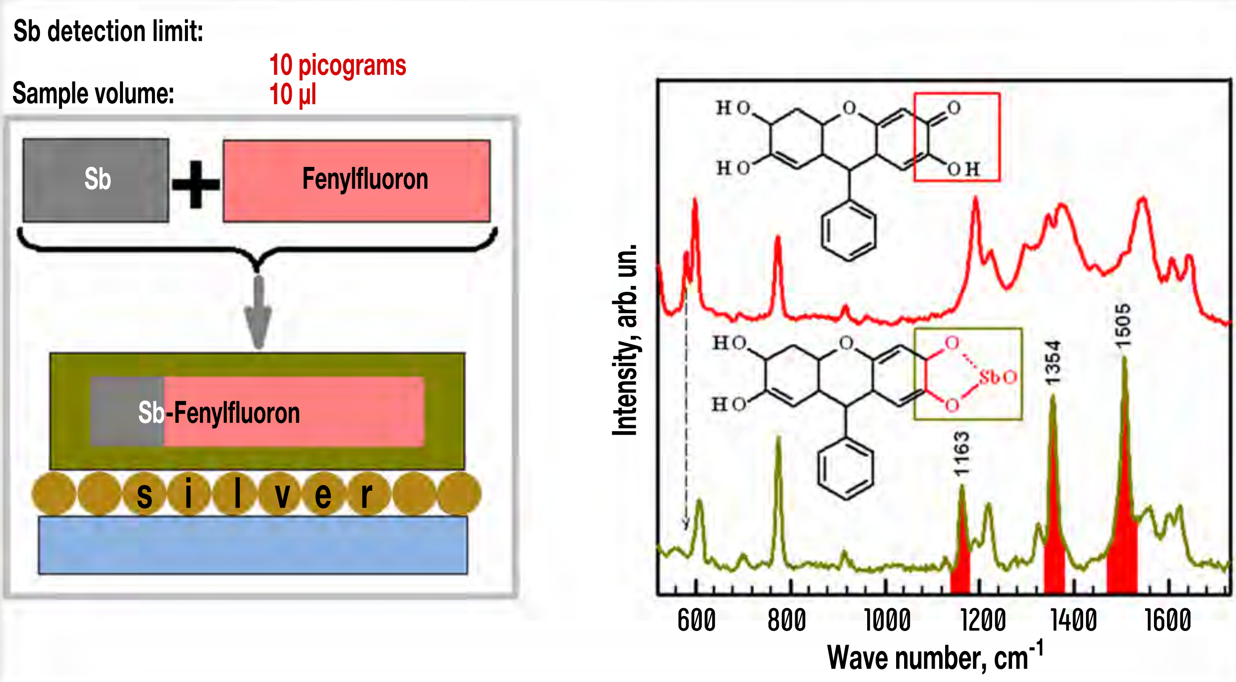
Method for determination of heavy metals

A highly sensitive method for detecting heavy metals was developed. The method is based on the analysis of the intensity of SERS lines of a metal complex with an organic reagent. This approach allows one to determine the absolute contents of antimony at the level of 10 picograms, what is an order higher than the sensitivity of standard photometric methods for this type of metal.

Advantage of the method:

- selectivity, which is achieved due to the characteristic of the vibrational spectrum, as well as resonant excitation conditions

The method can be applied for environmental monitoring-detection and control of the presence of a number of heavy metals in drinking water, waste water and industrial waste, as well as for other analytical purposes.

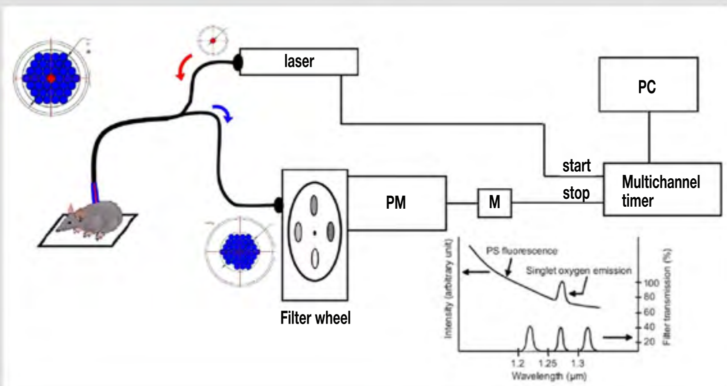


Laser dosimeter of singlet oxygen in biological tissues

The dosimeter is designed to study photochemical processes in vivo in biological tissues and cell cultures during photodynamic therapy. Control over the spectral-kinetic parameters of the singlet oxygen luminosity allows one to monitor the appearance and disappearance of oxygen in the medium and makes it possible to optimize the light mode of photodynamic therapy both in experimental and applied photomedicine. This device has unique parameters in the Republic of Belarus.

Technical parameters:

- radiation wavelength	532, 667 nm
- registration wavelengths	1200, 1250, 1275, 1300, 1350 nm
- minimal detectable quantum yield of luminescence of singlet oxygen	10^{-9} arb. un.
- operation mode	pulsed, 1 – 10 kHz
- power supply	~ 100…240 V / 50-60 Hz
- power consumption	not more than 1.0 kW
- experimental table area for placing sample irradiation units and light radiation registration	1 × 0.8 m^2
- overall weight without control PC	not more than 30 kg



Therapeutic laser for photodynamic therapy “PDT-laser”

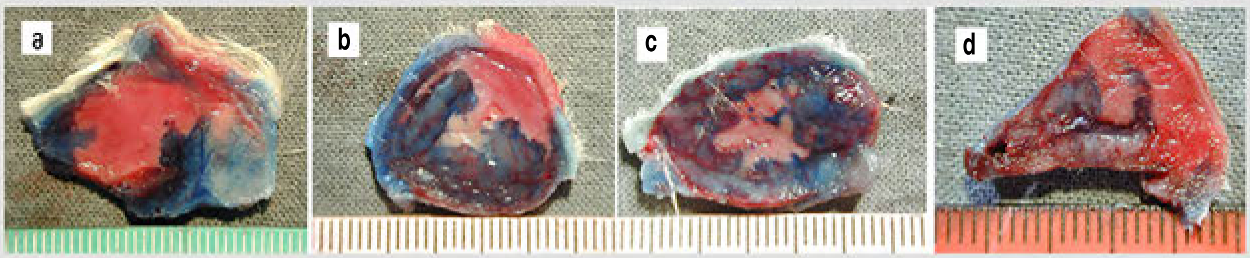
A therapeutic laser for photodynamic therapy "PDT-laser", which is registered and approved for application in medicine in the Republic of Belarus, has been developed by the teams of the Institute of Physics and LEMT Scientific and Technical center of the BelOMO.

Experience of operation with “PDT-laser” in Alexandrov Republican Scientific and Practical Center of Oncology and Medical Radiology showed its high efficiency in treatment of tumors of different localization.

Technical parameters:

- radiation wavelength	660 ± 5 nm
- radiation power adjustment range at the distal end of light guide	0.1 – 2.5 W
- exposure time adjustment range	10 – 3600 s
- adjustment discreteness of radiation power	0.1 W
- operation mode	continuous

Histological sections of Pliss lymphosarcoma tumor node of rats after PDT (a - d – various PDT modes)



The area of tumor tissue necrosis is marked red, the unaffected tissue is marked blue.

SCIENTIFIC CENTER "SEMICONDUCTOR TECHNOLOGIES AND LASERS"

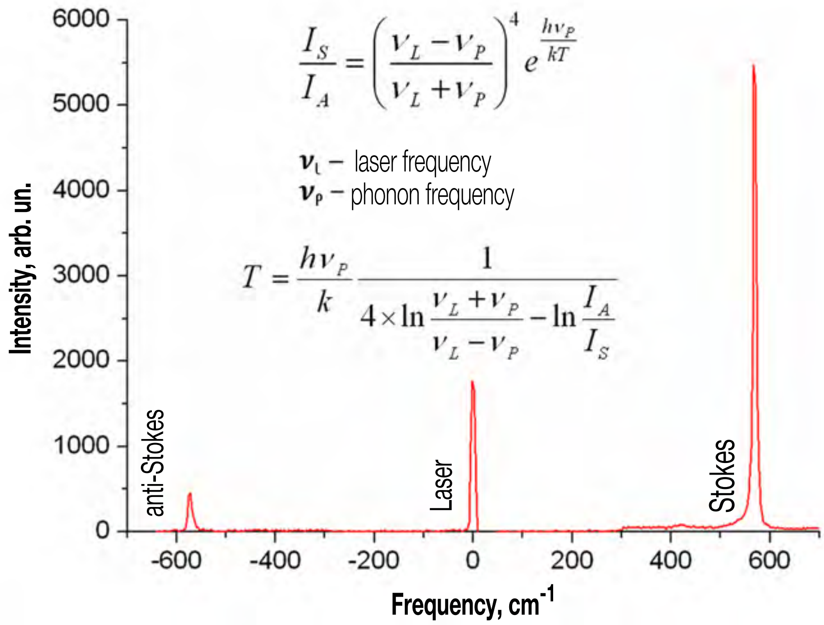
The main research directions are:

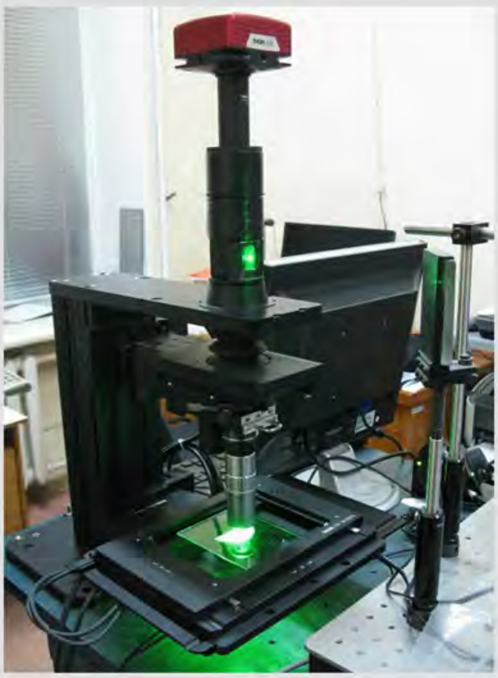
- molecular beam epitaxy of III-nitrides (AlInGaN) for creating power and microwave transistors, UV photoreceivers, LEDs, laser diodes, sensors and solar cells
- optic, luminescent, laser and electrical characterization of semiconductor layers, quantum wells and quantum dots, nanocolumns and nanomaterials
- research and characterization of laser media, LEDs, semiconductor lasers with optical, injection and electronic pumping, including micro-powder lasers with random generation, solar cells and luminophores
- development of optical and electrical methods for monitoring the temperature fields of microwave monolithic integrated circuits (MIC) and other semiconductor structures for determination of their properties and reliability
- creation of diode - pumped microlasers based on heterostructures with quantum wells and quantum dots (blue-orange spectrum range), as well as lasers with random generation, including "white" ones
- creation of new instruments based on LEDs and lasers for optical radiometry, photopolymerization, remote temperature detection, control of semiconductor wafers, heterostructures and solar cells

Setup for control of temperature fields of microwave MIC with laser Raman spectroscopy method

The setup is designed for temperature fields mapping using confocal microscopy of laser radiation Raman scattering in working semiconductor instrument structures of microwave MIC with submicron spatial resolution. The local temperature is determined according to the ratio of intensities of Stokes and anti-Stokes components of the scattered laser radiation, which allows the determination of local temperature without reference to a certain material or ratio of elements in solid solutions. This also allows one to determine local temperatures in LEDs and on the output mirrors of laser diodes.

GaN Raman spectrum at room temperature





Technical characteristics of the setup:

- maximal resolution (XYZ) 1 μm
- temperature detection accuracy ± 2°C
- temperature registration range 0 ÷ 500°C

Local temperature is determined according to the ratio of intensities of the scattered light components, which allows one to exclude the contribution of varying mechanical stresses in heterostructure occurring due to uneven heating to the temperature value determined by the spectral shift of the Stokes component (standard method).

Technology for molecular - beam epitaxy of nitride heterostructures

New generation material:

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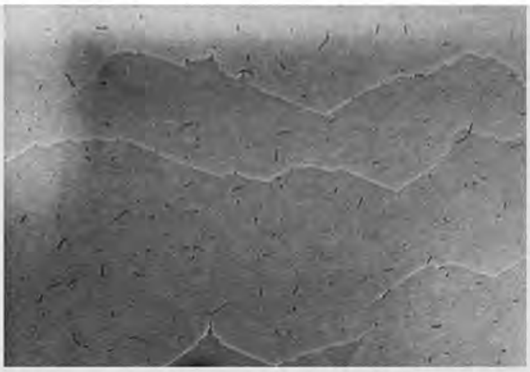
Gallium nitride (GaN) possesses a number of advantages over traditional Si and GaAs, such as:

- ability to work at high temperatures
- resistance to radiation
- higher efficiency of devices
- high density and mobility of electron gas in heterostructures AlGaN/GaN allows one to produce on their basis powerful microwave and power transistors

Applications of gallium nitride (GaN):

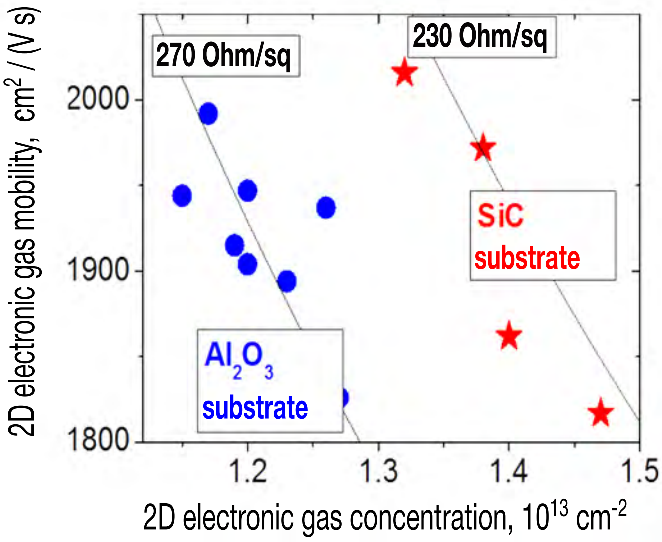
- in inverters, power supplies, drivers of new generation electrical devices with improved mass-dimensional characteristics, working in extreme conditions, including space
- for creating microwave amplifiers and microwave paths of communication systems
- in active phased antenna arrays (AESA)

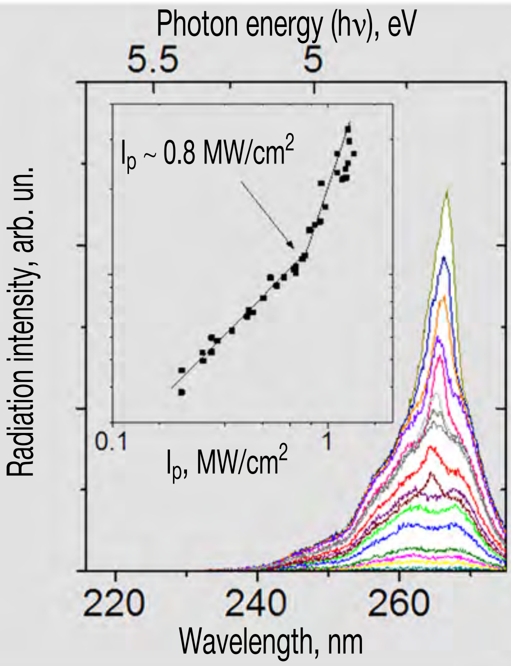
Achieved results:



The technology for AlN layer growth in step-flow mode is developed, which provides a roughness of ~ 0.7 nm.

The developed growth technology made it possible to create transistor heterostructures with two-dimensional electron gas on sapphire and silicon carbide substrates with characteristics corresponding to the best world analogues.



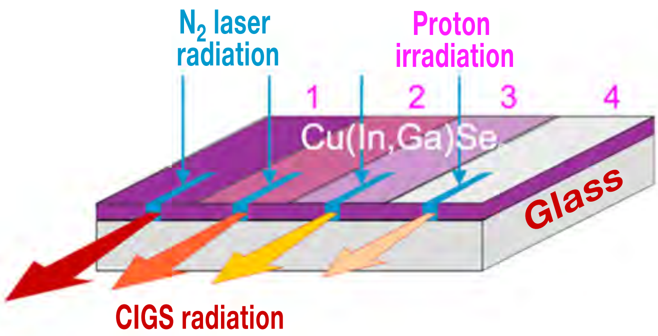


AlGaN layers were grown that showed stimulated radiation in the UV spectrum region with relatively low threshold values

Nitrides can be used for realization of almost all known communication, sensor and micromechanical technologies.

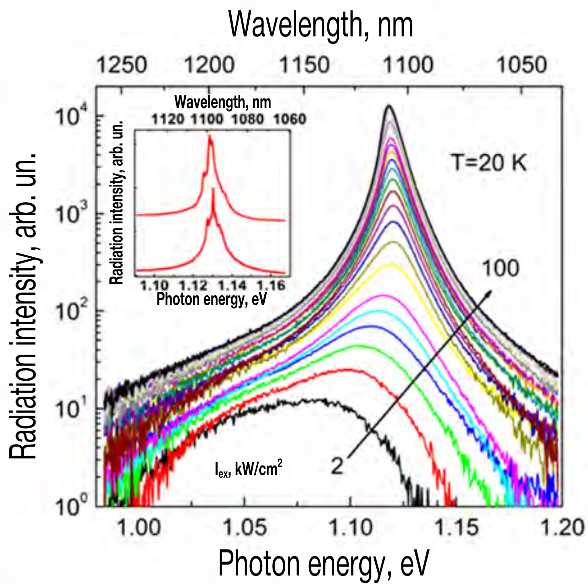
Materials for solar cells of new generation

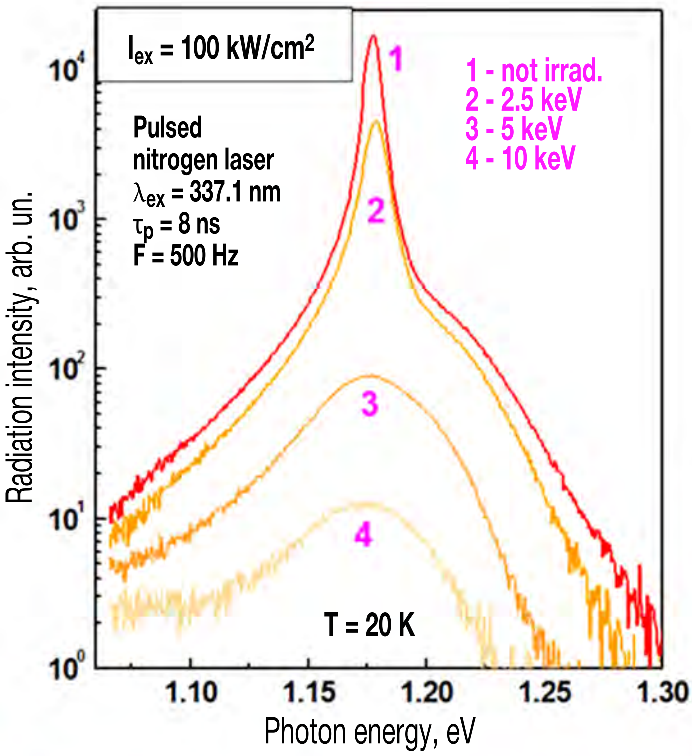
Stimulated and laser radiation in multicomponent straight-band semiconductors was detected and the mechanism of radiation recombination was established, which leads to their occurrence in film structures intended for creation of new generation solar cells.



The layout of CIGS film excitation with nitrogen laser radiation to obtain stimulated and laser radiation.

The mechanism of radiation recombination is established - recombination in electron-hole plasma.





Proton irradiation reduces the quality of thin films structure due to the formation of defects and this leads to disappearance of the stimulated radiation.

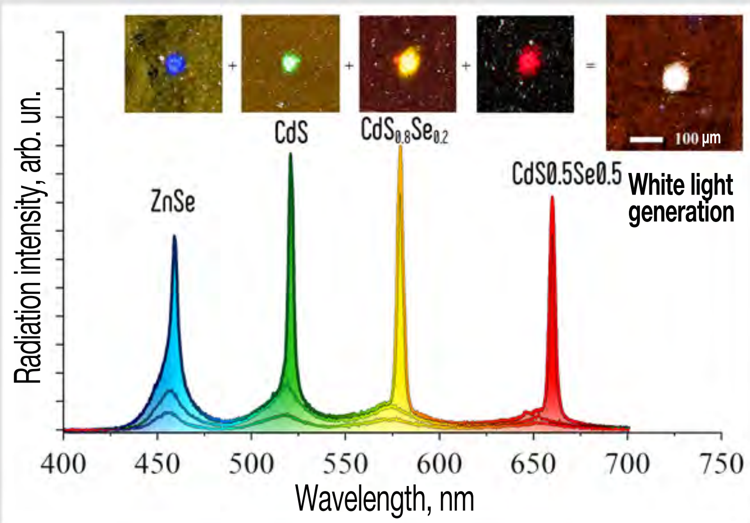
"White" laser with a mixture of micro-powders of $A^{II}B^{VI}$ semiconductors as a lasant material

Laser with generation of "white" radiation on the mixture of micro-powders of $A^{II}B^{VI}$ semiconductors with general formula $Zn_xCd_{1-x}SySe_{1-y}$ was designed and developed for the first time. The generation of radiation is achieved simultaneously on four wavelengths in lasant material from a mixture of densely packed micro-powders of ZnSe (460 nm), CdS (520 nm), $CdS_{0.8}Se_{0.2}$ (580 nm) and $CdS_{0.5}Se_{0.5}$ (660 nm) at a threshold density of excitation power of about 1 MW/cm^2 with pulsed radiation on 390 nm. The laser effect is a result of the occurrence of random feedback loops ("random lasing") in each type of scattering crystallites. Radiation at four wavelengths is mixed and as the result "white" radiation is formed, which propagates throughout the space angle without a given direction.

Key features of the "white" laser are:

- simple construction (there are no complex mirror resonators)
- low spatial coherence (the radiation is distributed throughout a space angle without the specified direction)
- ability to apply the lasant material to the surface of any shape

These features open up such areas of application of this type of laser as image visualization in television systems, information processing and transmission, biosensors in medicine (study of micro-damages in human tissue and bone), in friend-or-foe identification systems, in lighting technologies.



Radiation spectra of the white laser lasant material from a mixture of micro-powders of $A^{II}B^{VI}$ semiconductors optically pumped with $Ti:Al_2O_3$-laser radiation at 390 nm in the range from 0.5 MW/cm^2 to 4 MW/cm^2 at room temperature and images of the active regions generating laser radiation.

SCIENTIFIC CENTER “PHYSICS OF PLASMA”

Currently the scientific activity of the Center is connected with the development of new priority directions of plasma physics and plasma technologies aimed to expanding of plasma application in the economy, adaptation of new technological processes and productions, which is very important for the innovative development of the Republic of Belarus.

The main research directions are:

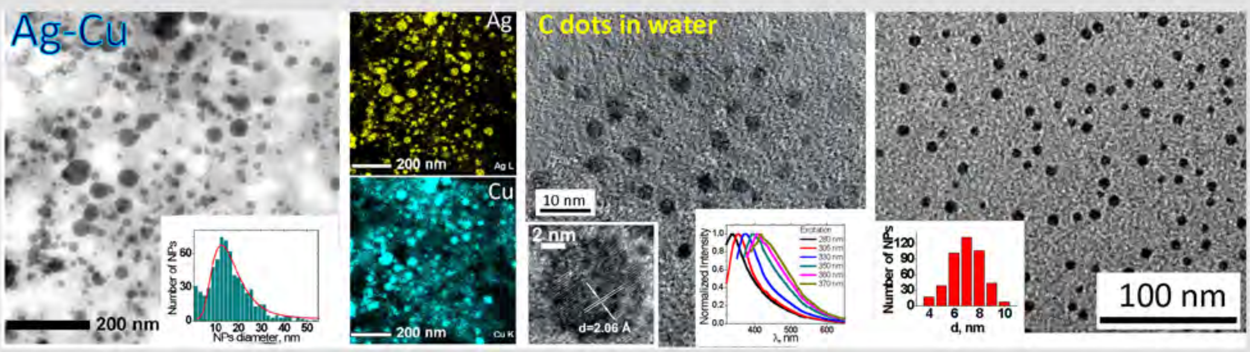
- plasma-activated synthesis of nanoscale structures under laser ablation and electric discharges in liquids, laser-induced modification of the formed nanoparticles
- development of laser microanalysis methods for quantitative determination of the elemental composition of materials, including 2D and 3D components distribution
- physics and chemistry of plasma formations induced by laser radiation and electrical discharges in liquids and gases
- nonlinear phenomena in plasma interaction with electromagnetic waves; plasma instability, development of methods for increasing the efficiency of plasma heating with electromagnetic radiation and creating fast-switching plasma periodic band structures for the control over the propagation of high-power microwave radiation
- physics of glow discharges of atmospheric pressure and development of new plasma methods and devices for hydro-carbons conversion, plasma medicine and microwave electronics on their basis
- interaction of plasma and laser radiation flows with materials. Plasmon dynamics of near-surface optical and combined discharges, development of new methods and diagnostic tools for pulsed plasma and control over the technological processes
- physical bases of laser-plasma and plasma-dust technologies (laser-plasma engines, methods and devices for processing materials and modifying their physical and chemical properties, synthesis of nanostructured thin-film coatings and hetero-structures)
- development of methods for combined plasma, acoustical and electromagnetic modification of microheterogeneous materials and biological objects

Produced nanoparticles:

Ag-Cu alloy nanoparticles

Carbon quantum dots

Tungsten carbide nanoparticles



Air plasma jet generator

Plasma medicine is a new direction of science that combines plasma physics and plasma chemistry with biology and medicine.

The developed instrument generates an air plasma jet containing nitrogen reactive particles and having a bactericidal effect on cells of various organization levels, as well as healing effect at treating infected wounds.

Technical parameters:

- discharge current	10-50 mA
- source voltage	3,5 kV
- power consumption	50 W
- main gas* (from 2 to 7 l/min)	air

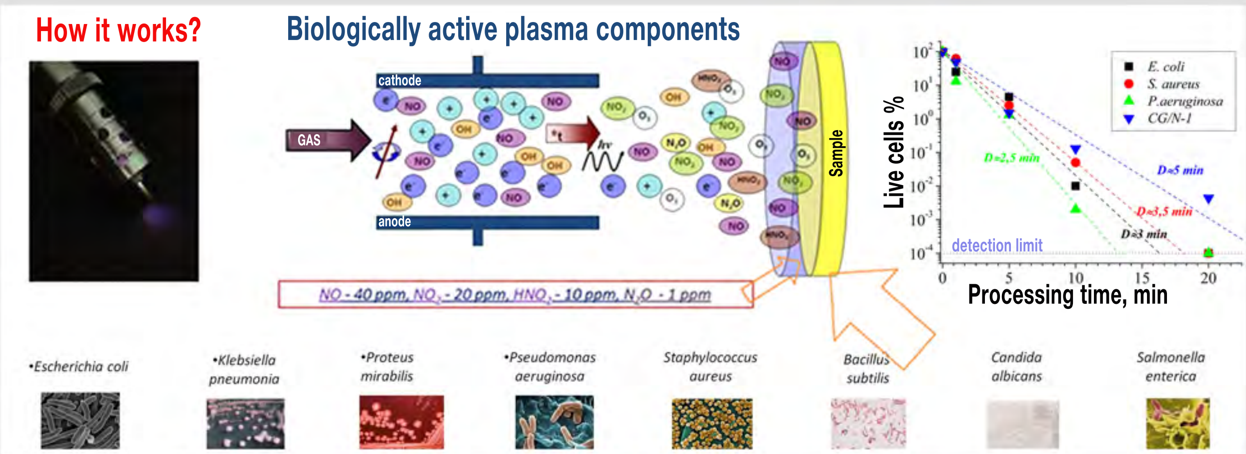
*** It is possible to use another gas.**

Advantages of plasma medicine:

- control, stimulation and catalyzation of biological processes in living tissues
- providing a therapeutic effect at sterilization and wound healing
- stopping of bleeding during a skin diseases treatment, including burns
- can be used for heat-sensitive surfaces, including skin and mucous membranes

Peculiarities:

- application of a glow discharge at direct current at atmospheric pressure in the air
- application of chemically and biologically active molecules as bactericidal factors: (NO, N_2O, HNO_2, O_3)
- no DNA destroy

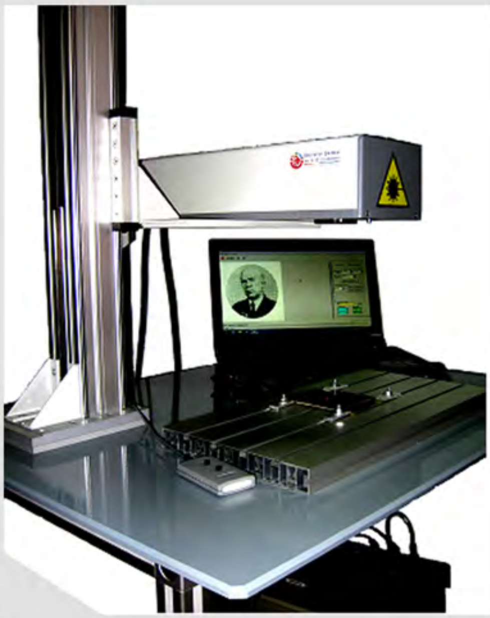


High-speed laser marker

Increased efficiency of high-frequency pulse-periodic laser application ($5 < f < 150$ kHz) for engraving and cutting a wide range of materials at atmospheric air pressure has been experimentally shown.

Piezoelectric and electromechanical light deflectors and a laser marker, providing multiple increase of laser marking speed have been developed and patented.

On the basis of completed developments, using a fiber ytterbium laser PIL-0.5-100-20-10 a prototype of a high-speed laser marker that provides precision marking of products from a wide range of materials, cutting thin metal foil, semiconductor and ceramic plates has been developed, manufactured and tested.



Technical parameters:

- type of laser	diode-pumped pulsed-periodic ytterbium fiber laser
- laser radiation wavelength	1060 ± 10 nm
- pulse repetition frequency	20 – 100 kHz
- pulse duration	100 ± 10 ns
- pulse energy	0.5 mJ
- average output power	10 / 20 / 50 W
- laser lifetime	> 30 000 hours
- power consumption	120 / 150 / 240 W
- marking field	60 x 60 / 110 x 110 /175 x 175 mm^2
- beam speed	< 8 m/s
- overall weight	35 kg
- overall dimensions	640 x 500 x 600 mm^3

Laser-plasma microthruster

A new concept of a laser-plasma microthruster with solid and liquid propellants for correction the orbit of new-generation microsatellites has been proposed based on studies of laser effects on a wide range of materials.

Thrust in a single pulse
$4{,}7 \cdot 10^{-2}$ N ± 5 %
Specific impulse
4 000 s ± 5 %

Thrust in a single pulse
$4{,}8 \cdot 10^{-3}$ N ± 5 %
Specific impulse
4 587 s ± 5 %

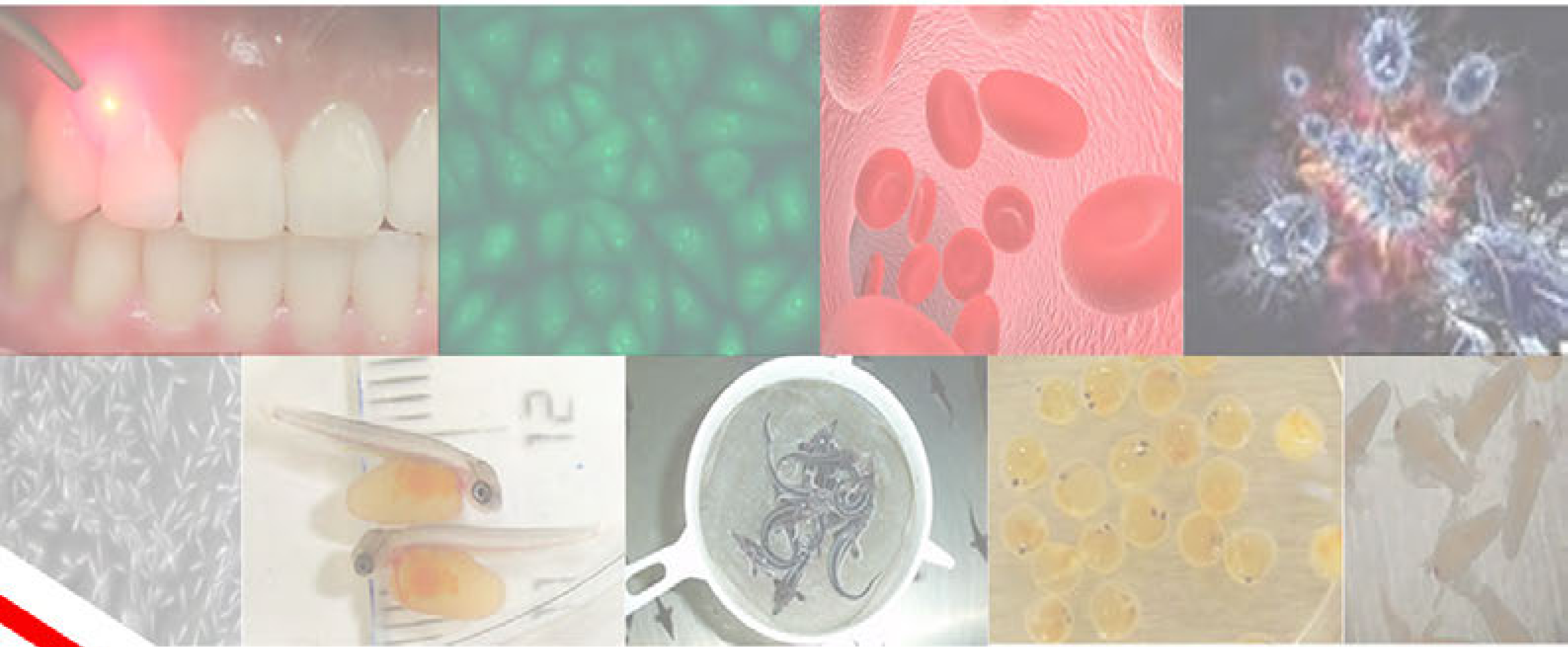
Experimental samples of laser-optical and target blocks of laser-plasma microthrusters with diode-pumped Nd:YAG mini-lasers (wavelength 1.064 μm) as well as erbium laser-based ones (wavelength 1.54 μm) have been developed, manufactured and tested.

The low-thrust laser-plasma microthruster is currently considered as a promising tool for correction of space orientation of nano- (having weight from 1 to 10 kg) and microsatellites (having weight from 10 to 100 kg). Such space vehicles can only be controlled by small single thrust impulses, which are practically not available for stationary electric jet engines.

SCIENTIFIC CENTER "LASER-OPTICAL TECHNOLOGIES FOR MEDICINE & BIOLOGY"

The main scientific directions are:

- investigation of interaction of coherent laser radiation with inhomogeneous media
- mathematical simulation of thermomechanical effects of pulsed laser radiation on heterogeneous biological structures. Improvement of laser medical technologies in ophthalmology and microsurgery on this basis
- investigation of photophysical and photochemical processes determining the antimicrobial effect of optical radiation
- laser-optical technologies in the microbiological industry (in microbial synthesis) and their instrumentation
- laser-optical technologies in the agricultural industry (ichthyology, reproductive biotechnologies, poultry farming, crop production) and their instrumentation
- investigation of the mechanisms of regulatory effect of laser radiation to biological systems of different levels of organization; methods of enhancing the regulatory effect of light
- photonics of biologically important molecules
- laser fluorescence kinetic spectroscopy (with picosecond resolution) of biomolecules and new fluorescent probes
- methods for diagnostics of pathological states of the human body and non-invasive monitoring of metabolites concentration using fluorescence spectroscopy and diffuse-reflected light spectroscopy
- instruments for low-intensity laser and antimicrobial photodynamic therapy for diagnosis and phototherapy of neonatal jaundice
- biocompatible light-sensitive and active media for holography, biophotonics and sensor applications
- tunable ultrashort-duration excitation sources for laser fluorescence spectroscopy and microscopy of biological objects



Phototherapeutic apparatus “LOTOS”

The apparatus “LOTOS” is intended for the treatment of infectious and inflammatory diseases of newborns and children of the first months of life.

Due to its wide functionality, “LOTOS” apparatus can be used for the treatment of diseases of various etiologies, which can hardly be treated with medication, by affecting the lesions with a size of 50x50 mm (using laser module).
Remote emitters can be used for hard-to-reach lesions (ears, etc.).

Technical parameters:

- laser type	continuous-wave diode laser
- laser radiation wavelength	λ_1 = 405 nm
	λ_2 = 650 nm
- maximal power of laser radiation density (for laser module)	10 mW/cm^2 (adjustable)
- maximal laser radiation power (for remote emitters)	50 mW (adjustable)
- operation mode	manual, timer
- power supply voltage	220 V / 50 Hz

Distinctive features of the phototherapeutic apparatus “LOTOS” are:

- opportunity of application of methods of antibacterial photodynamic therapy with photosensitizers used in clinical practice and the method of photoregulatory therapy
- opportunity of a significant increase of biological activity and therapeutic effect of radiation due to the combined treatment of the lesions with polarized radiation of purple and red spectrum regions during photoregulatory therapy
- opportunity of discrete regulation of laser radiation parameters

Phototherapeutic apparatus “MALYSH”

The phototerapeutic apparatus “MALYSH” is intended for the treatment of physiological (non-infectious) hyper-bilirubinemia of newborns. The disease is caused by excessive accumulation of a toxic cholechrome bilirubin in the blood and subcutaneous tissue, which gives the skin a characteristic golden - yellow color. If emergency measures are not taken, the presence of a high concentration of bilirubin in the infant's body may affect its physical and neuropsychiatric evolution and can also be a direct reason of death. According to the American Academy of Pediatrics, jaundice occurs in about 50-60% of full-term newborns and in 80% of preterm newborns. At the same time, phototherapy is the most effective and widespread method of reduction of bilirubin level in the blood of newborns. At the average at least 10% of all newborns take phototherapy.

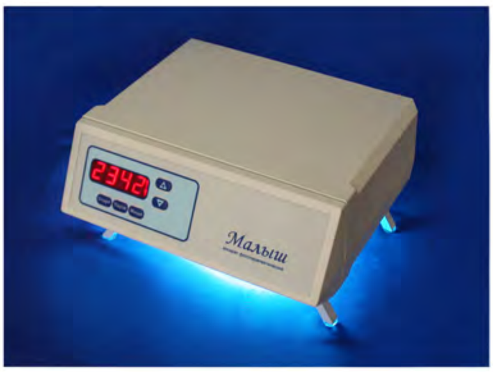
Phototherapeutic apparatus "Malysh" has been created on the basis of a modern led element base and has no analogues in the effectiveness of treatment of jaundice (hyperbilirubinemia) of newborns.
The instrument was awarded a gold medal at the International Exhibition–Congress "High technologies. Innovations. Investments" in St. Petersburg.

Operation principle:

Treatment of hyperbilirubinemia (jaundice) of newborns is based on exposure to the surface of the baby's body with light of blue-green spectrum region, corresponding to the bilirubin absorption band. The therapeutic effect is achieved by photo-conversion of bilirubin into photoisomers, the excretion speed of which is higher than that of bilirubin.

Increasing (comparing to analogues) of the effectiveness of phototherapy of jaundice is achieved by:

- selection of the spectral range in which the screening effect of hemoglobin is lower
- higher radiation power density on the surface of the baby's body
- opportunity of adjustment of the affected radiation intensity depending on the disease severity
- uniform distribution of radiation power density over the surface of the baby's body
- increase of percentage of a substance characterized by the maximum rate of excretion among bilirubin photoisomerization products.



Diagnostic apparatus "ANKUB Spectr"

Diagnostic apparatus "ANKUB Spectr" is designed for non-invasive detection of bilirubin level and monitoring of treatment of any type of baby's jaundice. The instrument can be used at hospital departments for the newborns, intensive therapy departments and directly in the doctor's room.

Advantages:

- no-pain non-invasive measurements
- minimal costs for analysis
- quick results
- easy operation
- opportunity of connection to the information system to save the results of bilirubin measurement for subsequent analysis

The instrument can be used before, during and after phototherapy. Bilirubin measurements are carried out in easily accessible areas (forehead, breast), so no special preparations of the newborns are required.
Due to the absence of need for blood sampling, the risk of injury or infection is minimized.
The device is low-weight and has excellent ergonomics. In addition, it is equipped with a built-in battery that ensures long-time operation.

Technical parameters:

- use	before, during and after phototherapy
- measuring range	0 – 400 μmol/l
- gestational age	27 – 42 weeks
- postnatal age	0 – 20 days
- weight of the patient	950 – 5000 g
- weight of the instrument	250 g

Operation principle:

The proposed instrument is a small-sized reflective photometer.
Optical radiation is directed to the skin of the newborn. As it passes through the skin, some part of the radiation is absorbed by the main chromophores of the skin - melanin, collagen, hemoglobin and bilirubin. The other part is scattered and is not taken into account. The remaining part of the radiation is reflected back to the instrument, analyzed by the microprocessor and the concentration of bilirubin is calculated according to the composition of the reflected radiation.
The optical layout of the analyzer with simultaneous measurement at several wavelengths allows one to compensate the influence of skin hemoglobin to the instrument indications. In fact, the degree of yellowness of the child's subcutaneous tissues is measured against coloring caused by the presence of hemoglobin in the blood.

Laser therapeutic apparatus “Rodnik-IP”

“Rodnik-IP” is an innovative apparatus for procedures of intravenous laser blood irradiation (ILBI).

Advantages of “Rodnik-IP”:

- ability to treat the blood with optimal mono- or combined (several spectral ranges) laser radiation in blue, red and near-infrared spectrum regions
- complete automatization of the phototherapy procedure (in case of combined radiation effect, switching of sources is automatic with no additional adjustment of the light guide for ILBI)
- opportunity of smooth regulation of laser radiation parameters depending on the nosology of the disease
- integrated system of laser radiation parameters control
- simple and intuitive control system
- ability of remote control over the device operation
- unique design, ergonomics and reliability
- protection against unauthorized changes of the operating mode during the procedure

Technical parameters:

- radiation source type continuous-wave diode laser
- laser hazard class II
- laser radiation wavelengths
  - λ_1 = 405 nm (blue spectrum region)
  - λ_2 = 650 nm (red spectrum region)
  - λ_3 = 780 nm (near-IR spectrum region)
- maximal radiation power in continuous mode at the exit of the main light guide 10 – 15 mW
- radiation power discrete adjustment range 1 mW
- procedure parameters setting mode automatic
- exposure time from 1 sec. to 60 min., with 1 sec. step

The use of apparatus “Rodnik-IP” allows one to reduce significantly the time of treatment, increase the time of remission, stabilize the course of diseases, as well as significantly reduce the number of complications.
“Rodnik-IP” is unified with other physiotherapy instruments, which makes it possible to use combined treatment methods and increase significantly therapeutic effectiveness.

Light guide heads for ILBI therapy

Laser therapeutic apparatus “Prometey-IP”

The apparatus is designed to treat a wide range of diseases of various origins and provides implementation of all phototherapy technologies currently used in laser therapy:

- treatment of the extra- and intra-cavity pathological localization
- transcutaneous laser and magnetic laser treatment of blood
- intravenous (intravascular) laser treatment of blood (ILBI therapy) using sterile disposable light guides
- treatment of biologically active points and zones (Zakharyin-Ged tender zones)

Technical parameters:

- radiation sources type	continuous-wave and pulsed diode lasers
- laser radiation wavelength:	
- continuous	λ_1 = 405 nm
	λ_2 = 650 nm
	λ_3 = 808 nm
- pulsed	λ_4 = 905 nm
- maximal continuous laser radiation power	50 mW
- maximal single pulse power	50 W
- maximal pulse repetition rate	10 kHz
- laser pulses duration	100 ns

The therapeutic apparatus is highly efficient due to:

- choosing the optimal laser radiation wavelength depending on the nosology and localization of the pathological lesions
- combined laser therapy with radiation of different spectral range
- combined magnetic laser therapy with maximum magnetic field strength in the area of laser radiation
- optical radiation modulation
- bactericidal effect of radiation from blue spectrum region corresponding to the absorption band of endogenous photosensitizers localized in microbial cells

The apparatus provides:

- use of light guide heads with different direction diagram of optical radiation and availability of hollow organs
- automatic control of operating radiation parameters during the laser therapy procedure
- regulation of operating radiation power, including the power of pulsed radiation
- measurement and automatic calibration of laser radiation power sources according to the sensor integrated in the instrument

Technologies for antimicrobial photodynamic therapy

Innovative methods for overcoming of pathogen microflora resistance have been developed, consisting in the use of antimicrobial photodynamic therapy of various diseases.

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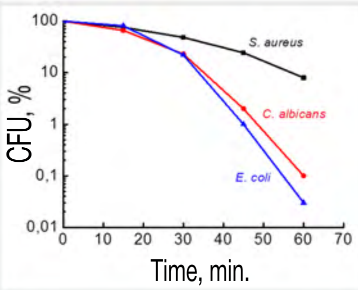
2018

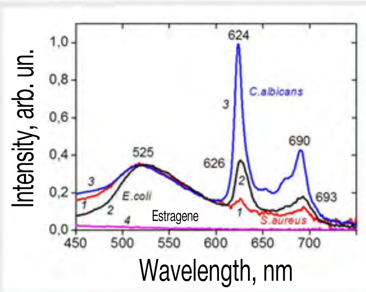
4 instructions have been developed and approved by the Ministry of Health of the Republic of Belarus for the following methods:

- therapy of infectious and inflammatory diseases of the newborns
- photodynamic therapy of patients with trophic ulcers and purulent-inflammatory diseases of the skin and soft tissues, various forms of cervical ectopia
- chronic periodontitis, laser methods for teeth canals disinfection, photodynamic therapy of Helicobacter-associated gastroduodenal diseases

The developed effective methods of antimicrobial photodynamic therapy are based on the activation of endogenous photosensitizers of porphyrin and flavin nature, localized in the pathogenic microflora, as well as on the use of drugs with photodynamic effect approved for use in clinical practice as photosensitizers.



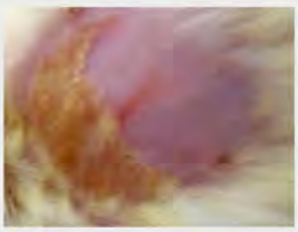
Kinetics of photoinactivation of various pathogens by laser radiation of violet spectrum region with no photosensitizing agents added



Fluorescence spectra of ether extract of S. aureus (1), E. coli (2) and C. albicans (3) and extractant (mixture of ethyl acetate /acetic acid) (4), λ_{ex} = 400 nm

The advantage of the first method is no need to use photosensitizers and identical photosensitivity of both gram-positive and gram-negative bacterial cells and fungi; the advantage of the second method is the availability of medicines used as photosensitizers.

Photodynamic therapy of dermatitis in animals (a rat as an example)



Control

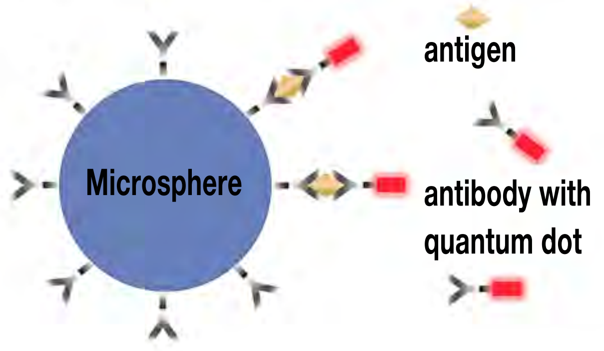
Amphotericin B

Light

Amphotericin B + light

Express automated laser analyzer of viruses

The analyzer makes simultaneous diagnostics of samples taken from several people for the presence of various viruses.
The method implemented in the device is based on registration of time-resolved fluorescence of semiconductor nanoparticles (quantum dots) as part of antigen-antibody complexes on the surface of polymer microspheres at two-photon excitation.

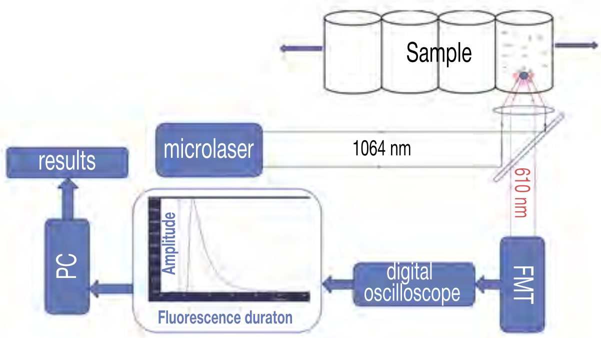


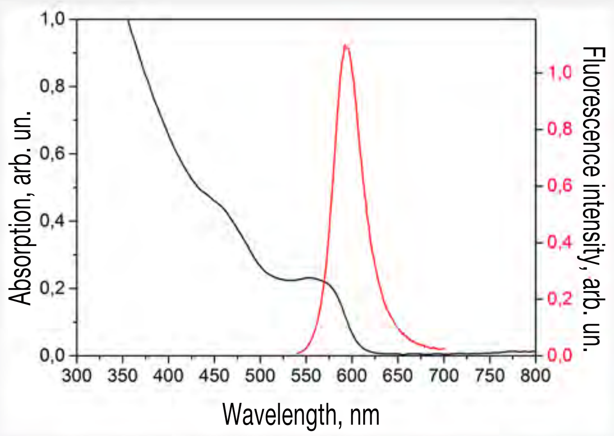
Technical parameters:

- diagnostic time	1 – 10 min.
- number of simultaneously tested samples	up to 5
- number of simultaneously detected virus types	up to 10
- minimal concentration of viral antigens in the sample	up to 10 fmol
- micro-laser pulse energy	up to 200 µJ
- repetition rate	up to 1 kHz
- pulse duration (FWHM)	up to 0.6 ns

Advantages of using quantum dots:

- narrow radiation spectrum
- opportunity of variation of the emission wavelength maximum by changing the size of quantum dot
- high quantum output of luminescence
- wide band of absorption spectrum





Distinctive features and advantages:

- allows doctors to diagnose correctly the disease during one medical examination of a patient and prescribe the most effective therapy
- use of such devices in medical institutions will reduce significantly the risk of viral epidemics

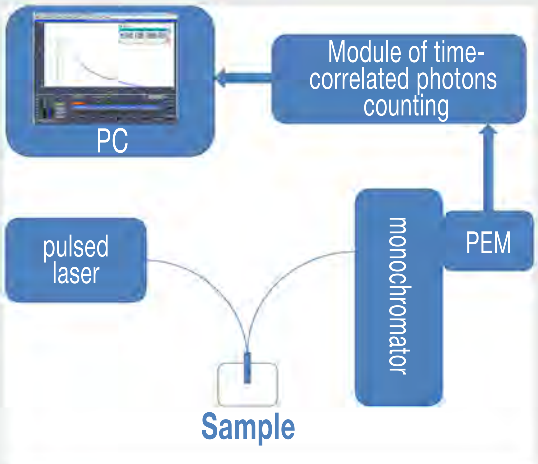
Laser setup and technology for cancer tissues diagnostics

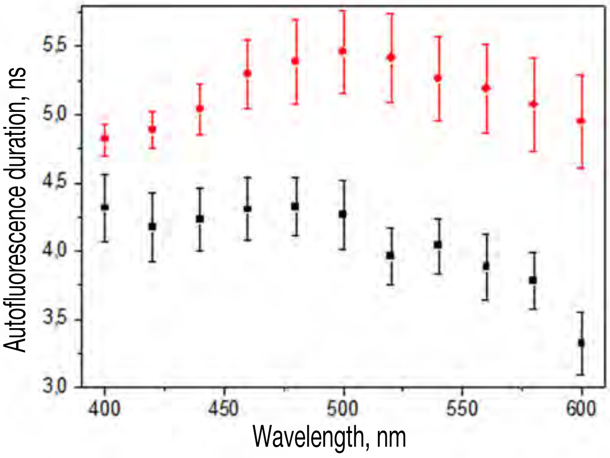
The instrument is designed for non-invasive express diagnosis of cancer tissues.

The main operation principle of the instrument is registration of time-resolved fluorescent characteristics of the tissue's own fluorescence and diffusely reflected light spectra with subsequent processing of the obtained data by multidimensional statistics analysis.

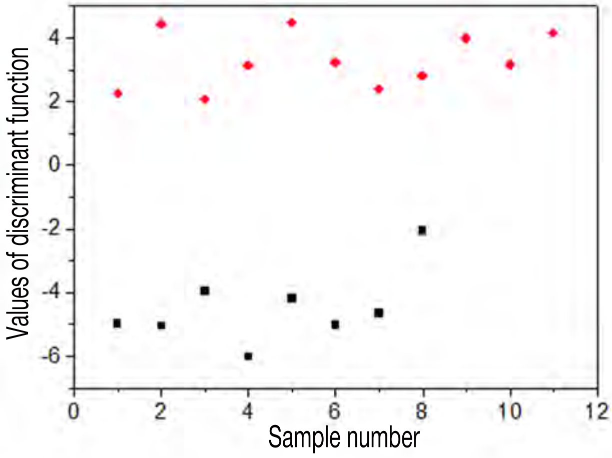
Distinctive features:

- applicability to various types of human tissue
- ability to diagnose tissues with high content of blood vessels
- no preliminary injections of drugs for diagnostics
- small size
- high-speed of sample scanning and diagnosis
- fiber-optic probe for supplying the sample with radiation





Dependence of the average autofluorescence duration on the registration wavelength for: healthy pituitary tissue (•) & pituitary adenoma (▪)



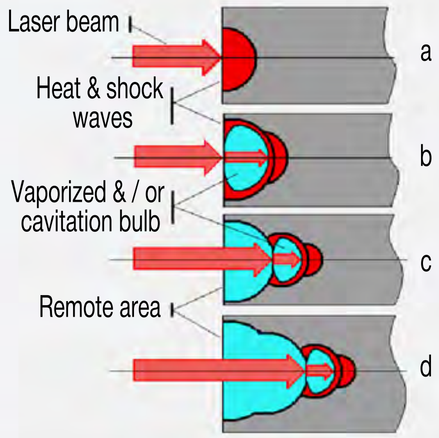
Healthy pituitary tissue (•) pituitary adenoma (▪)
Sensitivity and specificity of pituitary adenoma detection using discriminant analysis - 100%.

Advantages of the instrument:

- helps to reduce time and economic costs for pathological- anatomical diagnosis of cancer
- allows (in some cases) to refuse from the repeated surgical intervention
- increases the possibility of a positive result of the treatment process

Development of technology and equipment for laser low-temperature (cavitation) microsurgery

Methods of low-temperature (cavitation) laser photodestruction of biological tissues for particularly delicate surgical operations that require integrity of anatomical elements located on the periphery of the operating area are being developed.



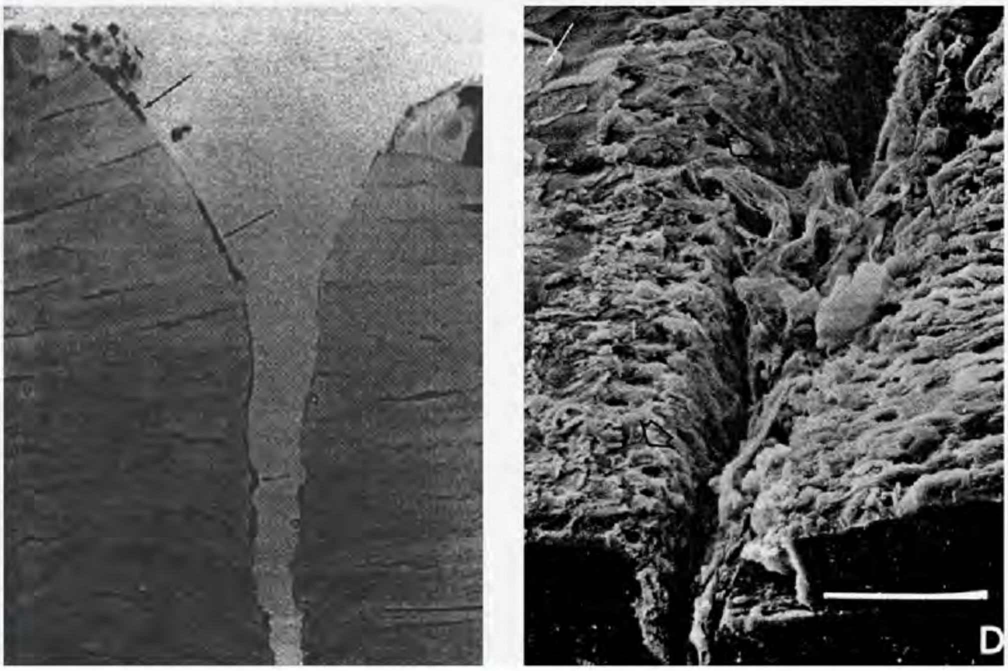
Potential applications:

- laser neurosurgery
- laser ophthalmology
- laser otolaryngology

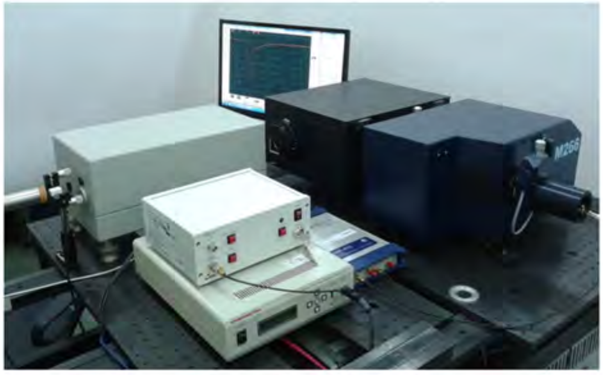
The method is based on the effect of generation of an acoustic (shock) wave during the short laser pulses are applied to biotissues. If the radiation power exceeds the threshold value, conditions for the formation of cavitation cavities are created in the negative phase of the wave. Mechanical destruction of the tissue is realized at heating levels that do not exceed one degree. Thus, thermal tissue damage (coagulation) at the borders of the operating zone is excluded.

The main feature of the technology is extremely low non-damaging thermal effect of radiation on tissues during operations.

Microphoto of the zone of laser dissection of cornea (D = 100 μm)



Picosecond laser spectrofluorometer
for highly sensitive analysis in physics, biology & medicine

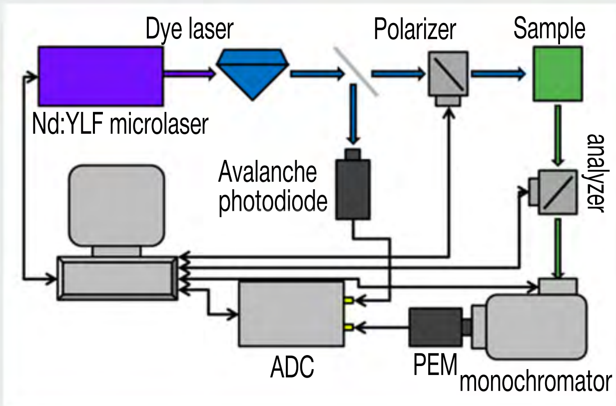


Spectrofluorometer operation modes:

- measurement of fluorescence decay kinetics and excitation lifetime
- measurement of fluorescence spectra with time resolution
- measurement of emission anisotropy kinetics
- measurement of polarization and fluorescence anisotropy spectra with time resolution

Technical parameters:

- excitation wavelengths range		
	Nd:YLF microlaser	349 & 523 nm
	DFB dye laser	380 – 750 nm
- excitation pulse duration		
	Nd:YLF microlaser	300 ps
	DFB dye laser	50 – 250 ps
- wavelengths registration range		350 – 800 nm
- temporal resolution		50 ps
- registration sensitivity		10^{-9} mol/l



Optical technologies for the microbiological industry

Methods for stimulation of the growth and metabolic activity of industrially valuable microorganisms (including yeast cultures) have been developed using optical radiation from lasers and LEDs to optimize technologies for obtaining biological products. The main advantages of this approach over the use of specific biostimulators are low material costs and universality, since radiation sources are not energy-intensive, long-living and can be used to stimulate microorganisms of different taxonomic affiliation.

Small-sized laser source for spectrum-tunable subnanosecond & picosecond radiation pulses “WIPER TOPAZ-PS”

“WIPER TOPAZ-PS” dye laser with distributed feedback (DFB) is designed to produce narrow-band spectrum tunable radiation of subnanosecond and picosecond duration when excited by radiation of the 2nd and 3rd harmonics of subnanosecond solid-state diode-pumped Nd:YAG-, Nd:LSB- and Nd:YLF-microlasers.

Application areas:

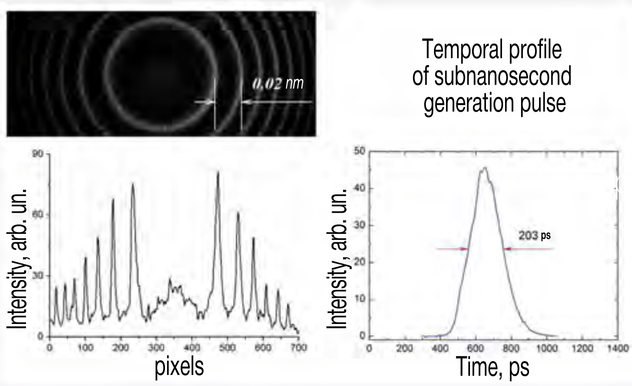
- spectroscopy
- photochemistry
- biomedicine
- biophysics
- solid state physics
- semiconductor physics
- optoelectronics
- ecology

Technical parameters:

- excitation wavelengths	349, 354, 523.5 & 532 nm
- adjustment area	370 – 900 nm
- band width	0.01 – 0.03 nm
- generation efficiency	up to 50 %
- pulse duration	
in subnanosecond mode	0.2 – 0.5 ns
in picosecond mode	20 – 70 ps
- pulse energy stability	0.6 – 3.0 %
- pulse repetition rate	up to 100 Hz
- overall dimensions (L × W × H)	39 × 22 × 22 cm
- weight	6.8 kg

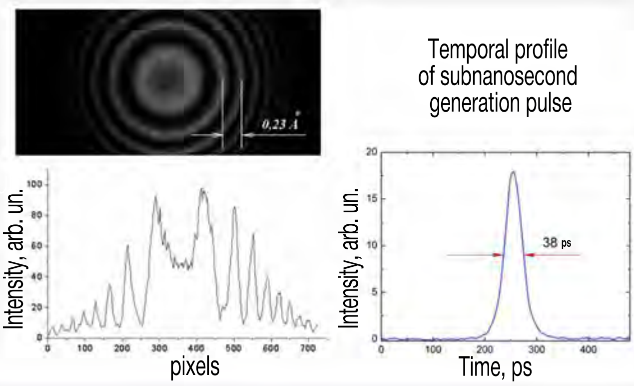
Distinctive features:

Difference of the DFB laser from traditional dye lasers with the same spectral characteristics consists in:
- absence of the external resonator and spectral-selective elements
- significantly high efficiency of pumping radiation conversion into a narrow dye generation line
- wider adjustment range without exciting the background of enhanced spontaneous radiation
- ability of direct obtaining of spectral-limited single picosecond pulses at nano- / subnanosecond excitation
- ability to work in frequency mode with no pumping of active medium through the cuvette
- simple construction, reliability and easy to use



Spectrum of high-power subnanosecond pulse generation

(λ = 570 nm, $\Delta\lambda_{0.5}$ = 0.0067 nm)



Spectrum of picosecond pulse generation

(λ = 570 nm, $\Delta\lambda_{0.5}$ = 0.0075 nm)

Photostimulator for hydrobionts

Institute of Physics of NAS of Belarus together with the Institute of Fish Farming of NAS of Belarus, as well as the Department of Ichthyology and Fish Farming of Belarusian State Agricultural Academy accomplished comprehensive studies of the laws of action of laser radiation and LED light sources on embryos and sperm of valuable species of fish (sturgeon, salmon, rainbow trout), as well as the main specie of pond fish farming in the Republic of Belarus – carp.

The performed research served as the basis for creating innovative equipment based on laser and LED sources integrated into technological equipment that is usually used in fish farms for incubating reproductive products of fish (tray-type incubators, Weiss incubators).

The photostimulator provides a 1.3-1.4 times increase of the reproduction function of fish, fertilizing capacity of sperm and increasing the output of marketable products in the conditions of fish-farming industrial complexes. There is also an increase in the resistance of hydrobionts to adverse environmental factors (toxicants, high or low temperature, lack of oxygen).

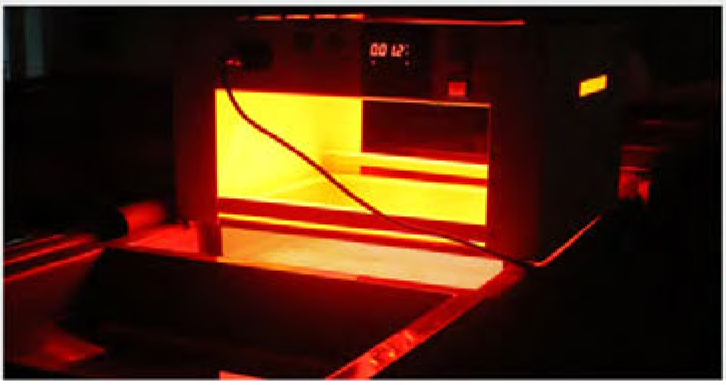
Technical parameters:

- operating radiation wavelength	λ_1 = 650 nm
	λ_2 = 780 nm
- exposure mode	continuous (modulated)
- timer	1 s – 60 min.

- compatible with the technological equipment for the incubation of reproductive products of fish

Original ways of stimulating effect on embryos, sperm and producers of reproductive products of fish, as well as technical solutions implemented at equipment creation are protected by patents of the Republic of Belarus and Russian Federation.

Photostimulator based on a tray - type device



Photostimulator based on the Weiss device

Apparatus “Svetophyte”

Application areas:

Instrument “Svetophyte” is designed for growth-stimulating and phyto-therapeutic (antibacterial) treatment of vegetable seeds before planting in opened and closed ground.

Technical parameters:

- operating radiation wavelength	λ_1 = 405 nm
	λ_2 = 445 nm
	λ_3 = 650 nm
- exposure mode	continuous

Distinctive features:

- the instrument provides antibacterial treatment of pathogens localized in seeds by stimulating endogenous photosensitizers with blue spectrum region radiation
- red spectrum region radiation has a stimulating effect on seed germination and plant growth
- the instrument ensures the implementation of environment-friendly technologies in seed material processing, allowing one to avoid the use of pesticides and other chemical reagents

Cucumber seeds (Strumok F1)

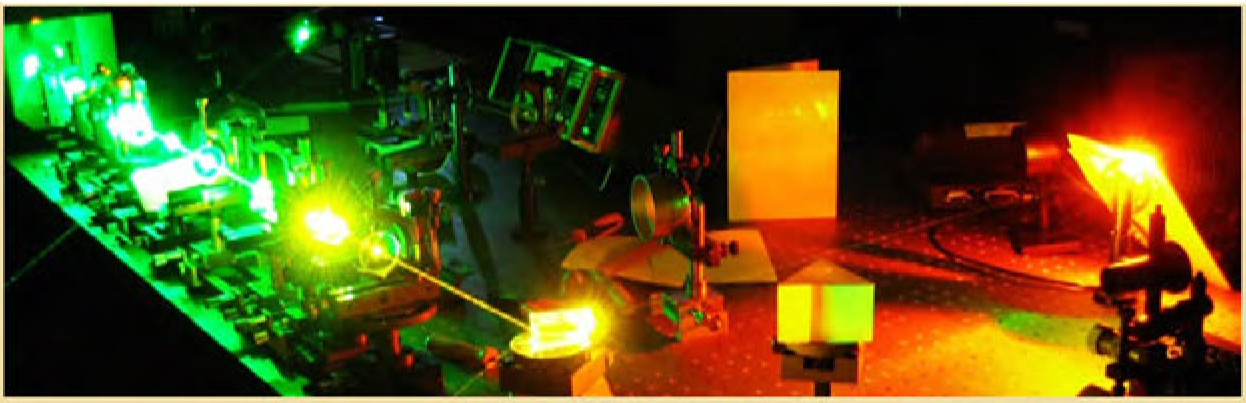
Control

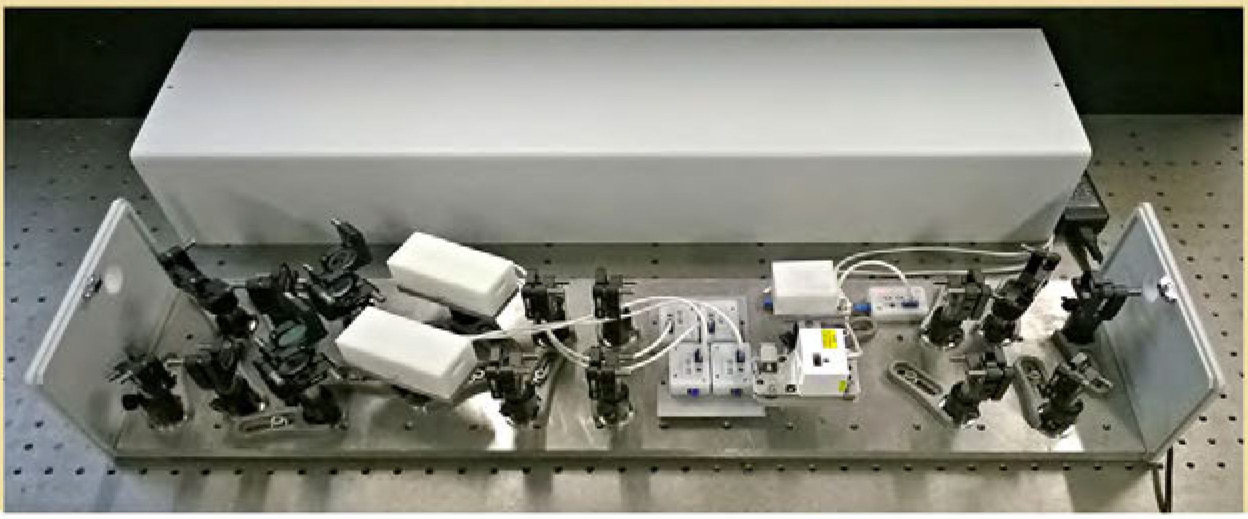
After treatment with the apparatus “Svetophyte”

SCIENTIFIC CENTER “NONLINEAR OPTICS & ACTIVATED MATERIALS”

The main research directions are:

- development of technology for the synthesis of new optical materials, including nano-oxide glass ceramics and gel-glasses
- investigation of photophysical and photochemical processes in crystalline, ceramic and nanostructured media, their spectral-luminescent, nonlinear-optical and generation properties
- development of new non-organic Stokes and anti-Stokes luminophores, as well as luminescent metal-organic compounds
- investigation of biological media and organic molecules using luminescent spectroscopy, Raman spectroscopy (RS) and surface-enhanced Raman scattering (SERS)
- study of generation dynamics of solid-state lasers with longitudinal diode pumping
- study of nonlinear optics of structured light fields, as well as thermo-optical processes in high-power laser systems
- development of methods for out- and in-resonator nonlinear optical conversion of laser generation frequency to the ultraviolet, visible, near- and mid-infrared spectrum ranges in crystals, liquids and gases
- development of prototypes of specialized continuous, quasi-continuous, and pulse-periodic solid-state laser systems





Completely solid-state multi-wave diode-pumped laser system

Purpose:

- laser system is intended for generation of pulsed radiation at one or more wavelengths from the set of **11 wavelengths**, overlapping ultraviolet, visible and short-wave infrared spectrum ranges.

Technical parameters:

- generation wavelength	266, 355, 532, 559, 563, 588, 599, 621, 639, 1064 & 1571 nm
- pulse energy (depending on the wavelength)	15 - 160 mJ
- pulse repetition rate	10, 20 Hz
- pulse duration	9 - 15 ns
- beam divergence	1.5 - 6.0 mrad
- power consumption	< 950 W
- weight without/with power supply	58 / 69 kg

Distinctive features and advantages comparing to the analogues:

- wide spectral range of generation (operating frequency range covers 6 octaves)
- low power consumption due to the use of diode pumping
- completely solid-state approach (no liquid refrigerant)
- flexibility in choosing the working wavelength (modular design)
- possibility of simultaneous generation at several wavelengths

Application:

- environmental protection (lidar probing of the atmosphere)
- medicine
- spectroscopy

Pulse energy, nm	mJ
266	25
355	30
532	100
559	30
563	35
588	20
599	20
621	15
639	15
1064	160
1571	30

Multiwave quasi-continuous laser system

Purpose:

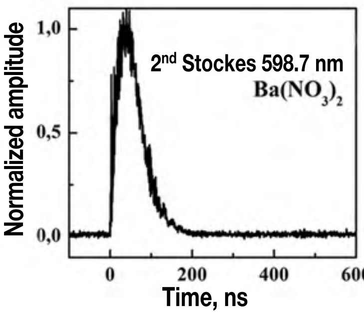
Laser system is designed to generate quasi-continuous radiation at one or several of the **17 wavelengths** in the visible and near-infrared spectrum ranges

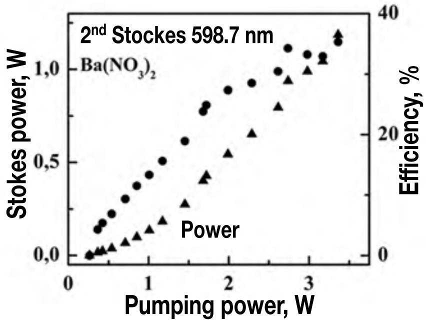
Application area:

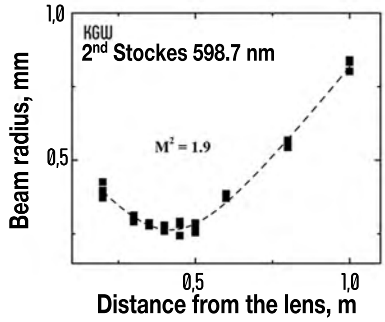
- environmental protection (lidar probing of the atmosphere)
- laser distance-measuring instruments
- biomedicine
- spectroscopy

Distinctive features and advantages comparing to the analogues:

- wide spectral range of generation
- completely solid-state approach
- possibility of simultaneous generation at several wavelengths

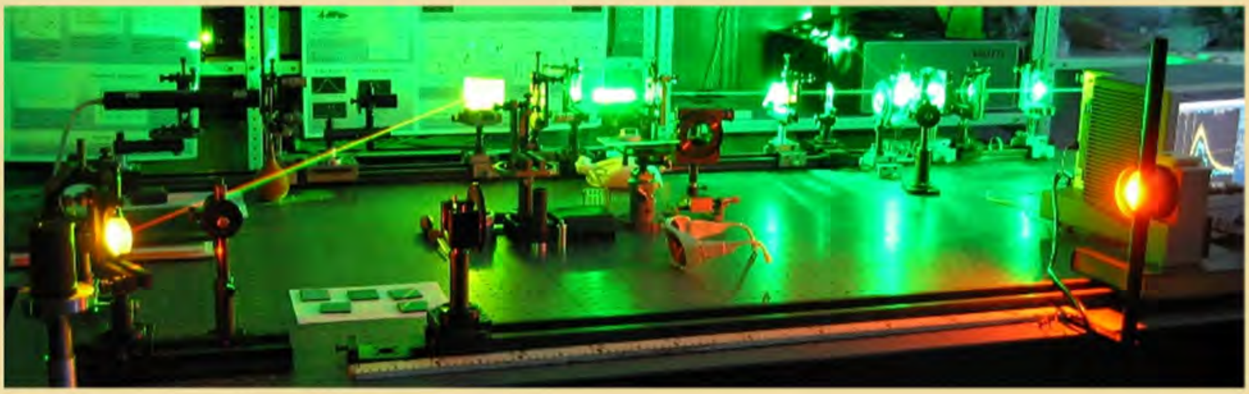






Technical parameters:

- generation wavelengths	532, 559, 563, 588, 599, 601, 639, 1064, 1159, 1178, 1197, 1272, 1316, 1369, 1410, 1493, 1598 nm
- average radiation power (depending on the wavelength)	0.1 – 1.5 W
- pulse repetition rate	1 – 4 kHz
- pulse duration	50 – 190 ns
- beam divergence	3 – 5 mrad



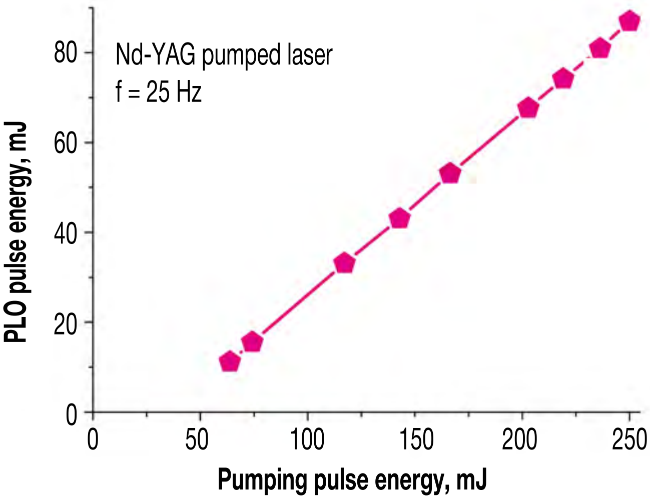
Eye-safe parametric light oscillator (PLO) on crystals $KTiOPO_4$ (KTP) or $KTiOAsO_4$ (KTA)

Purpose:

- PLO is intended for nonlinear optical conversion of pulsed radiation from Nd^{3+}-pumped laser into eye-safe pulsed radiation at the wavelength of 1571 nm (KTP) or 1535 nm (KTA).

Application area of optical-electronic systems:

- environmental protection (lidar probing of the atmosphere)
- laser distance-measuring instruments
- detection and remote recognition

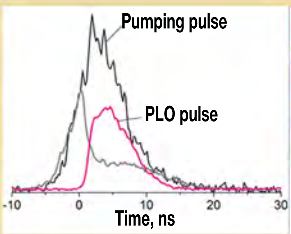


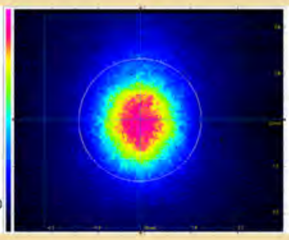
Technical parameters:

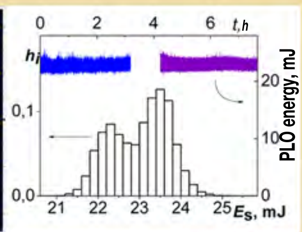
- Nd^{3+}-pumping laser wavelength	~ 1 μm
- eye-safe radiation wavelength 1571 nm (KTP-PLO) or 1535 nm (KTA-PLO)	
- average pulse energy PLO	20 – 100 mJ
- pulse repetition rate	up to 30 Hz
- pulse duration	10 – 20 ns
- beam divergence	~ 5 mrad
- long term stability	

Distinctive features and advantages comparing to the analogues:

- PLO operation in the running wave mode using a ring resonator, which allows one to eliminate feedback on pump radiation between Nd^{3+} laser and PLO without additional measures
- completely solid-state approach
- in the case of a linear PLO resonator (standing wave mode), the use of a circuit solution that allows one to eliminate the feedback on pumping radiation without any expensive Faraday insulators



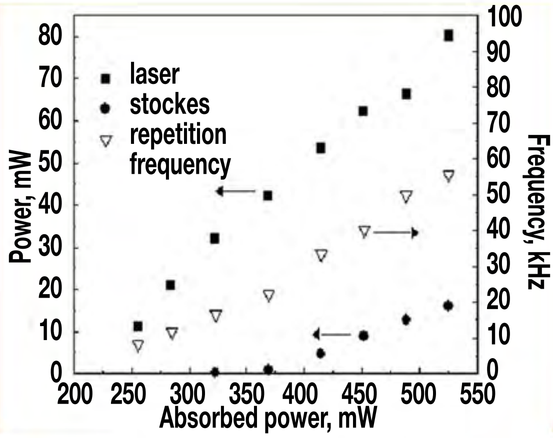




Diode-pumped microchip-lasers or microchip-lasers with SRS-conversion

Purpose:

Microchip-laser is designed for generation of pulsed radiation at one or two wavelengths in the range of 1 – 1.2 μm with the possibility of its nonlinear optical conversion to the UV or visible spectral region.



Technical parameters (device model 1):

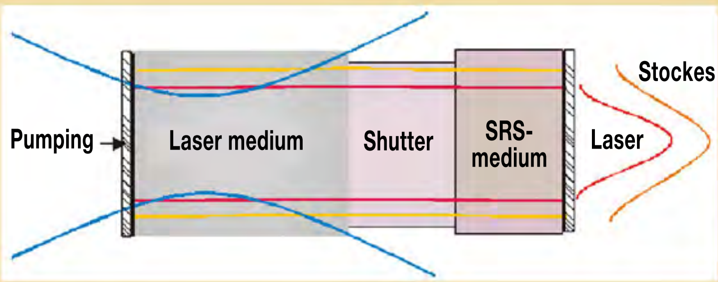
- generation wavelengths 1063, 1196, 598, 563, 532, 399, 383, 299, 282, 266, 239 nm
- average radiation power 1 – 80 mW (depending on the wavelength)
- pulse repetition frequency 1 – 60 kHz
- pulse duration 50 ps – 1 ns

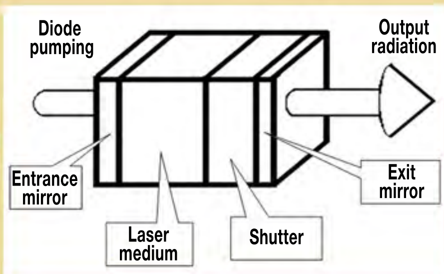
Technical parameters (device model 2):

- generation wavelengths 266, 355, 532, 1064 nm
- pulse energy up to1 mJ at 1064 nm
- pulse repetition rate 100 Hz
- pulse duration ~ 500 ps

Distinctive features and advantages:

- extremely compact design, easy to use, low power consumption
- single-mode and single-frequency generation mode
- possibility of generating at 2 wavelengths
- generation of short pulses
- high stability of output radiation parameters





New oxide materials for light conversion systems

A method for preparing yellow powder luminophore $Y_3Al_5O_{12}:Ce^{3+}$ with grain diameter of about 500 nm and internal quantum yield of luminescence more than 90%, which is a record value for highly dispersed phosphors has been developed. Lanthanum oxide as a doping material to this luminophore allows one to shift significantly (up to 50 nm) the barycenter of the luminescence band to the red spectrum region. Such luminophores can be applied in LED lighting systems and for the manufacturing of luminescent optical ceramics. Such ceramics is characterized by the increased thermal stability of luminescence – at T = 440 K, the decrease in its intensity is no more than 10%, which allows its application in high-power LED lighting sources.

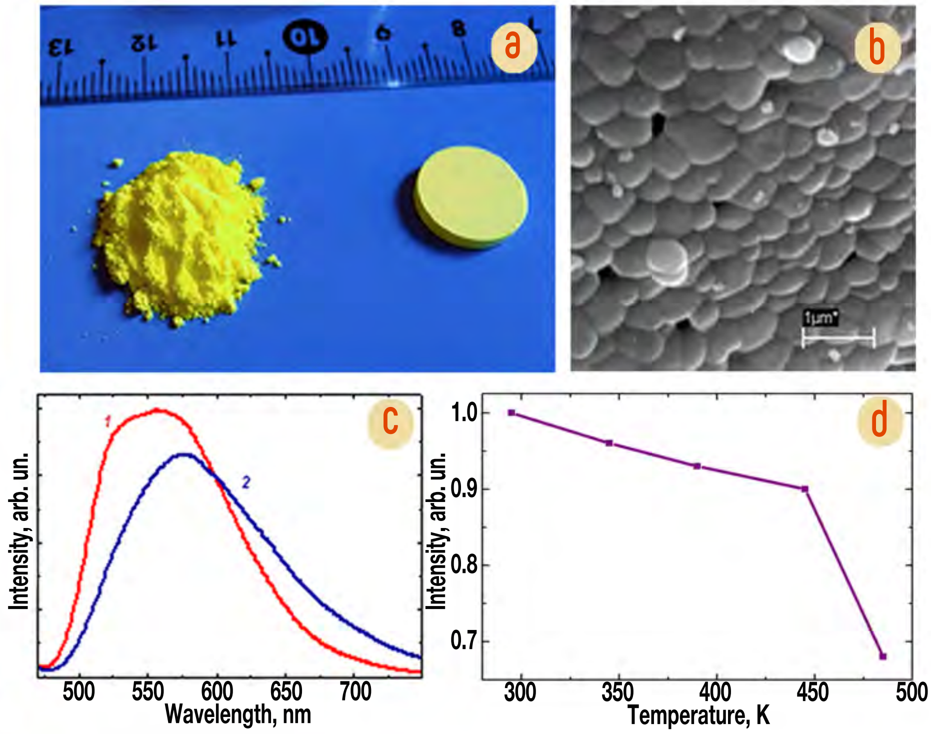
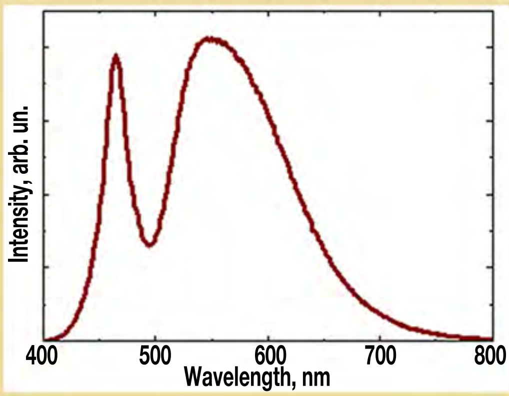


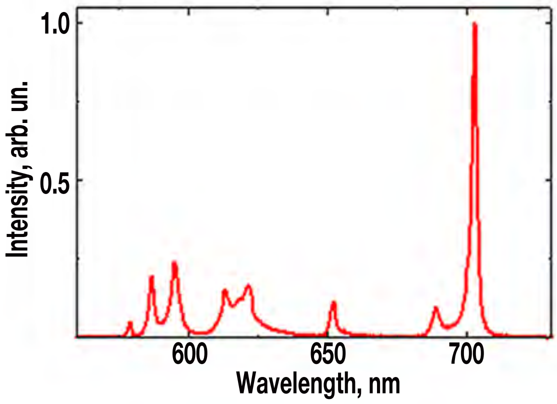
Photo of $Y_3Al_5O_{12}:Ce^{3+}$ luminophore and the ceramics obtained from it (a), micro-image of the luminophore (b), "quantum" luminescence spectra of the luminophore (c) without (1) and with a doping material La_2O_3 (2), dependence of the luminescence intensity of the ceramics on the temperature (d)

"Energy" radiation spectrum of two-component source "light emitting diode-luminophore"



Oxide films activated by Eu^{3+} ions have been developed. They are characterized by a record value of the luminescence branching in the transition of $^5D_0 \rightarrow {}^7F_4$ ($\lambda \approx 700$ nm), radiation of which falls on the area of minimum induced absorption. This allows one to recommend them as the active medium of planar lasers of corresponding spectral range.

"Quantum" luminescence spectrum of the oxide film alloyed with Eu^{3+}

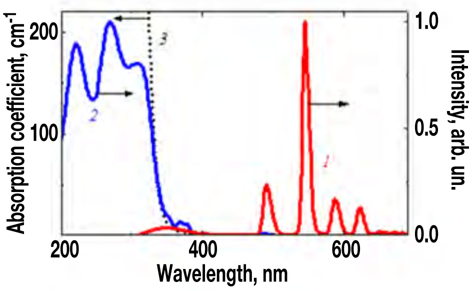


Activated glasses have been developed for:

- ultraviolet images visualization
- optical fiber extraction and manufacturing of a fiber-optic screen that visualizes x-ray images
- solar ultraviolet "downshifting" into the area of high spectral sensitivity of solar cells

Technical parameters:

- complete absorption of radiation with the wavelength of not more than 330 nm in the layer of 100 nm thick
- quantum output of sensitized luminescence of about 60% at excitation in the region of 280 – 330 nm and 85% at excitation with the wavelength of about 380 nm
- efficiency of radio-luminescence is comparable to that of a $CdWO_4$ single-crystal scintillator



1 - "quantum" luminescence spectra (λ_{ex} = 280 nm)
2 - excitation of luminescence (λ_{reg} = 545 nm)
3 - glass absorption spectrum

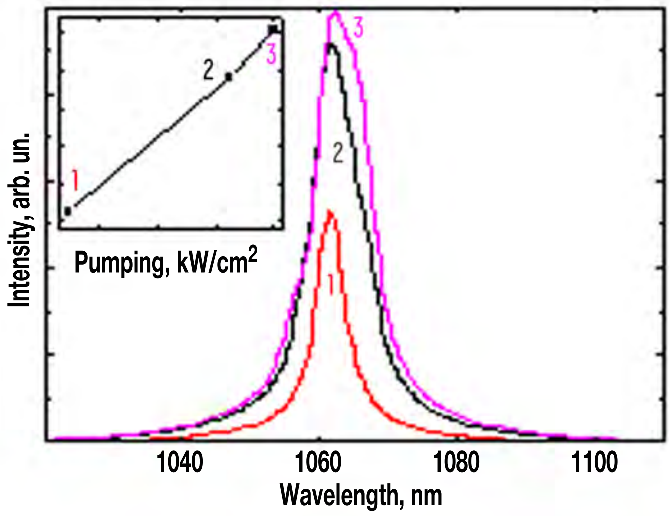
Photos of glass at the excitation wavelength of 254 nm (a) and 365 nm (b)

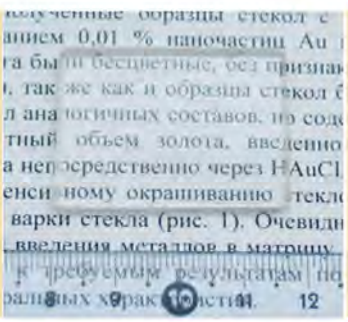
Yb-containing huntite-like glasses that are promising for the use as an active material for continuous-generation fiber lasers and microchip femtosecond lasers with high specific energy consumption have been developed. Laser radiation (at the wavelength of about 1060 nm with a threshold of about 60 W/mm^2) was obtained on a thin plate of such glass in a "deaf" semi-spherical resonator with led pumping in quasi-continuous mode (differential efficiency of 12.5%) and Q-switching mode.

Advantages:

- reduced crystallization capacity, allowing to extract the fiber
- low photo-bleaching and photo-darkening efficiencies
- maximal quantum yield of Yb^{3+} ions luminescence is about 94%
- low losses to co-operative luminescence of Yb – Yb pairs (two orders lower than for quartz glass under identical pumping conditions)
- large effective half-width of the amplification band (33 nm, which is 1.5 times higher than the same parameter for ytterbium-alloyed crystals of huntite and yttrium-aluminum garnet)
- high values of thermal conductivity (0,73 – 0,95 W/m · K) and the threshold of laser-induced destruction of the surface (27 J/cm^2)

Spectra of glass generation in quasi-continuous mode (1-3), dependence of generation energy on pumping power (inset):





Active glass element with composition (mol. %):
$1{,}5Yb_2O_3$–$8{,}5Y_{12}O_3$-$30A_{l2}O_3$-$60B_2O_3$

SCIENTIFIC CENTER “LASER TECHNIQUE & TECHNOLOGIES”

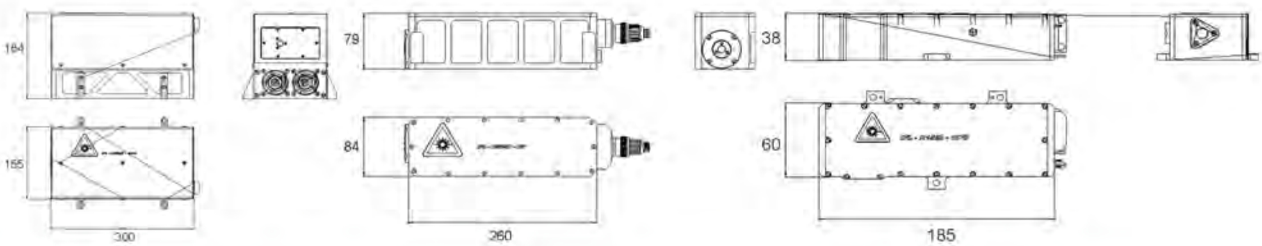
The main scientific directions are:

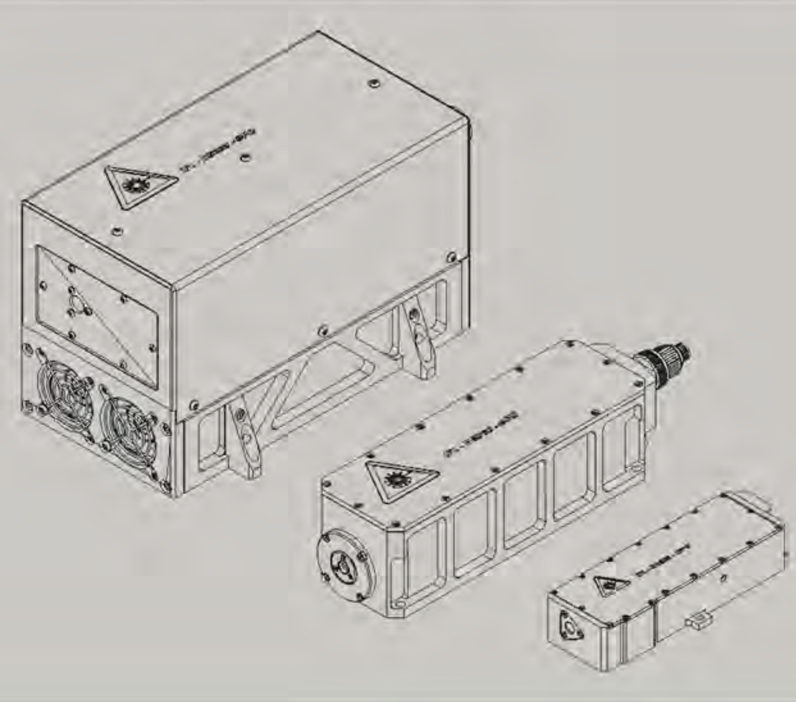
- investigations of nonlinear effects in laser systems
- development and creation of laser systems for distance measurement complexes, spectroscopy, lidar technology and medicine

Nd:YAG lasers with parametric light generation

IFL-N5030, IFL-N2560, IFL-N1520K & **IFL-N1520** – are reliable and compact Nd:YAG lasers with parametric light generation, conditionally safe for vision, with radiation wavelength of 1.57 µm, output energy of up to 50 mJ, pulse repetition rate up to 60 Hz, conductive or air cooling, external / internal synchronization, optimized for integration into optoelectronic systems, compact, designed for operation in temperature range of - 40 ÷ + 50 °C.

Type of laser	IFL-N5030	IFL-N2560	IFL-N1520K	IFL-N1520
Wavelength, µm	1.57			
Output pulse energy, mJ	50	25	15	
Pulse repetition rate, Hz	up to 30	up to 60	up to 20	
Beam diameter, mm	< 5			
Beam divergence, mrad	< 8		< 5	
Pulse duration, ns	< 10			
Cooling type	air / conductive		conductive	
Operating temperature range, °C	+ 10 ÷ + 40		- 40 ÷ + 50	+ 10 ÷ + 40
Dimensions (L × W × H), mm	300 × 155 × 185		260 × 84 × 79	185 × 60 × 38
Weight, kg			< 1.9	< 1



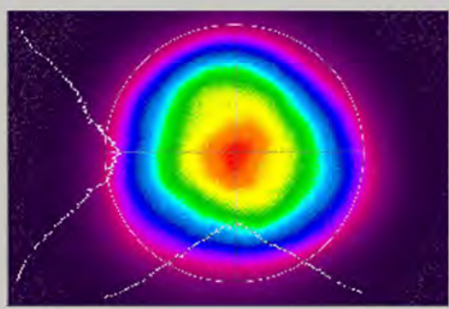


Nd:YAG lasers

IFL-N200, IFL-N200K, IFL-N40KT, IFL-N50SM, IFL-N100K & **IFL-N100-2I** are universal sources of laser radiation at the wavelength of 1064 nm, reliable and compact Nd:YAG lasers developed for research and technological applications and operation in the temperature range of - 40 ÷ + 50 °C.

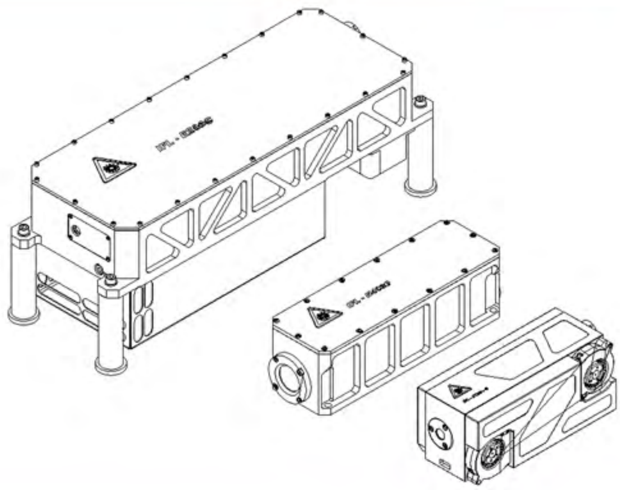
Type of laser	IFL-N200K	IFL-N40KT	IFL-N100K
Mode	multimode		
Wavelength, μm	1.064		
Output pulse energy, mJ	200	40	100
Pulse repetition rate, Hz	30, 100	30	
Pulse duration, ns	< 12	< 10	
Beam diameter, mm	5	30	5
Beam divergence, mrad	< 1.3	< 0.4	< 1.5
Beam quality parameter, M^2	< 1.5	< 2	
Cooling type	air \ conductive		
Operating temperature range, °C	- 40 ÷ + 50		
Dimensions (L × W × H), mm	420 × 155 × 74	266 × 84 × 79	200 × 88 × 84
Weight, kg	4	2	

Far field of the output beam



Main features:

- output energy up to 200 mJ
- pulse repetition rate up to 100 Hz
- compact design
- conductive and air-cooling
- external / internal synchronization
- lasers are vibration - resistant



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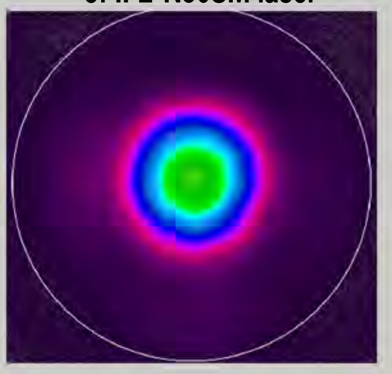
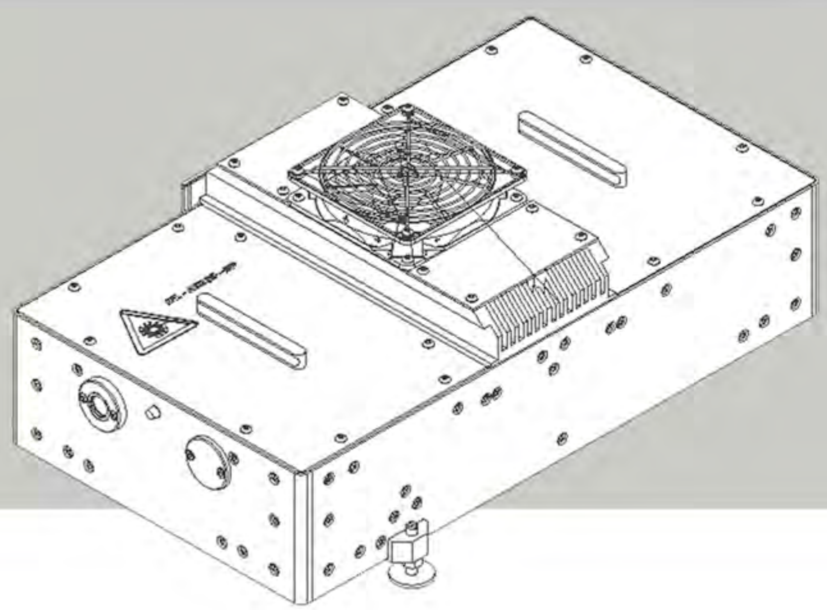
Type of laser	IFL-N200	IFL-N50SM	IFL-N100-2I
Number of channels	1	1	2
Mode	multimode	TEM_{00}	multimode
Wavelength, µm	1.064		
Output pulse energy, mJ	200, 60	50	100
Pulse repetition rate, Hz	30, 100		30
Pulse duration, ns	< 12	< 25	< 10
Beam diameter, mm	5	2	< 5
Beam divergence, mrad	< 1.2		< 0.8
Beam quality parameter, M^2		< 1.5	
Cooling type	conductive		
	liquid, air	liquid	
Dimensions (L × W × H), mm	447 × 165 × 84		500 × 280 × 203
Weight, kg	5		8
Delay between pilses, µs			1 – 100

Near field of the output beam of IFL-N50SM laser





Main features:

IFL-N200:

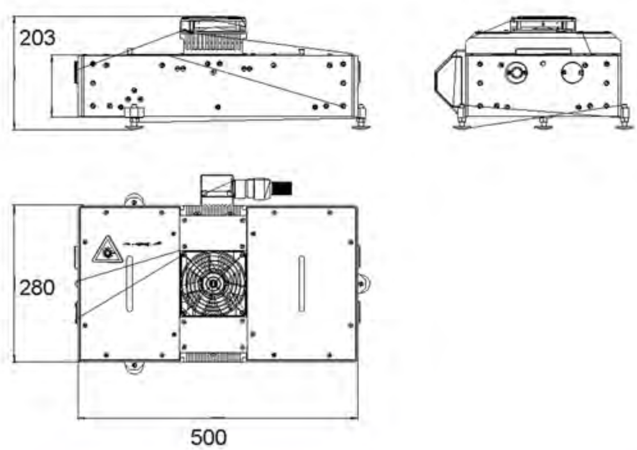
- radiation energy up to 200 mJ
- opportunity of increasing of pulse repetition rate up to 100 Hz
- connected to modules of the second, third and fourth harmonics

IFL-N50SM:

- Gaussian beam (zero transverse mode)

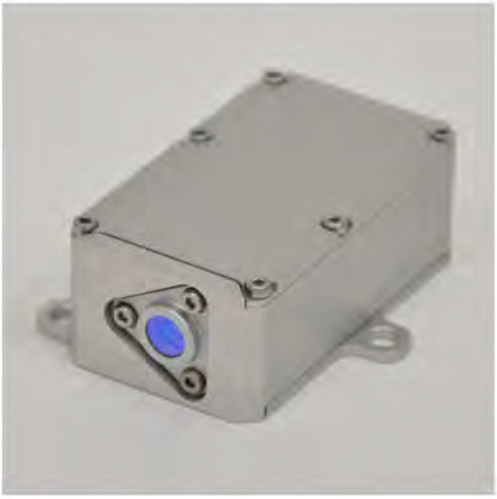
IFL-N100-2I:

- double-pulse laser for LIBS spectroscopy
- tunable delay between pulses 1 – 100 µs



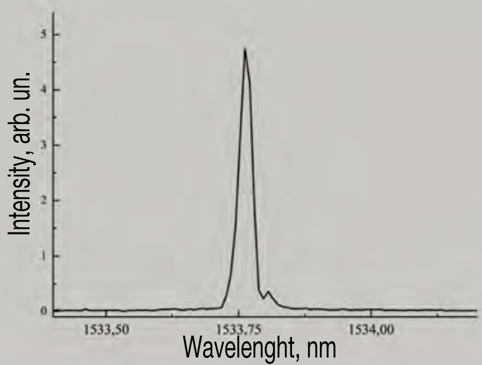
Erbium lasers

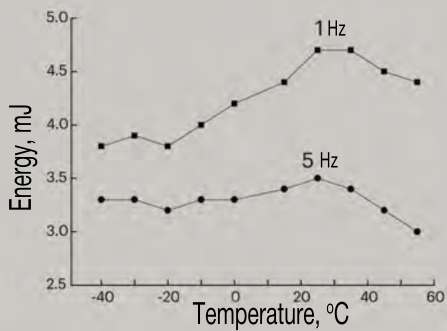
Compact erbium lasers **IFL-E25-P**, **IFL-E45-P**, **IFL-E85-P**, **IFL-E81-PT** & **IFL-E105-EO** are specially designed for application in the devices operated in a wide temperature ranges with shocks and vibrations.



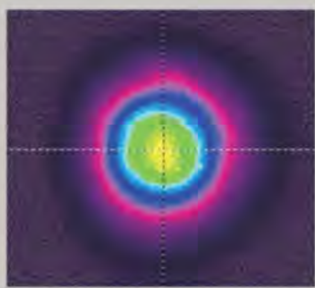
Type of laser	IFL-E25-P	IFL-E45-P
Mode	diode	
Modulation	passive	
Wavelength, μm	1535	
Pulse energy, mJ	2	4
Pulse repetition rate, Hz	up to 5	
Pulse duration, ns	< 15	< 10
Beam diameter, mm	< 0.5	
Beam divergence, mrad	< 4	
Beam quality parameter, M^2	< 15	
Cooling type	conductive	
Operation temperature,°C	- 40 ÷ + 60	
Dimensions (L × W × H), mm	60 × 34 × 22	
Weight, kg	< 60	

Laser radiation generation spectrum



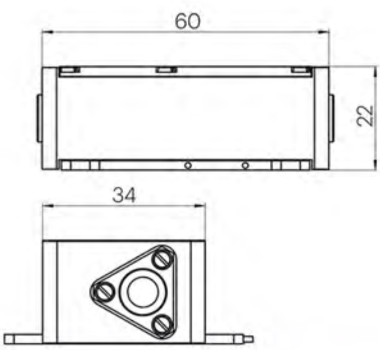


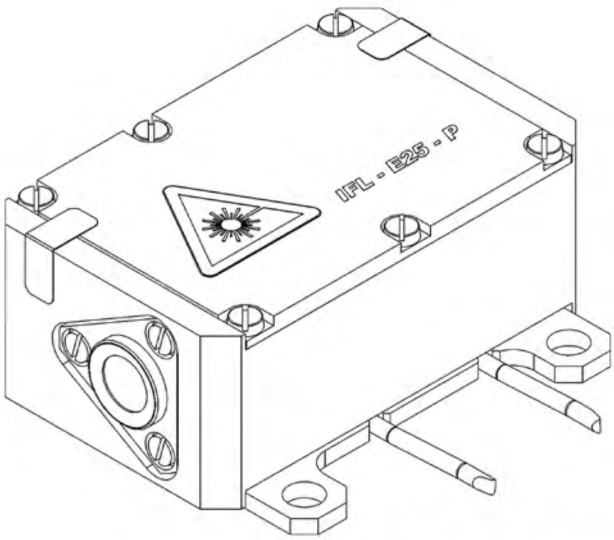
Laser generates Gaussian beam on TEM_{00} transverse mode



Main features:

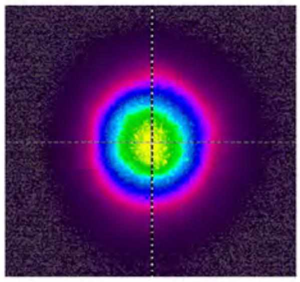
- lasers are resistant to vibrations up to 75 g
- do not require forced cooling
- hermetic housing



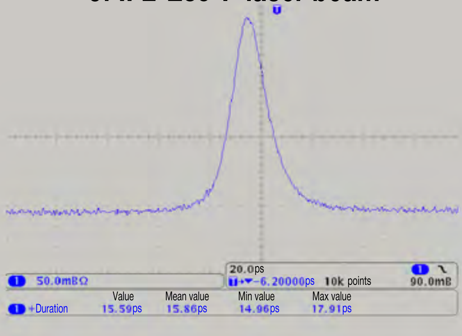


Type of laser	IFL-E85-P	IFL-E81-PT	IFL-E105-EO
Mode	diode		
Modulation	passive		active
Wavelength, nm	1535		
Pulse energy, mJ	8	10	
Pulse repetition rate, Hz	up to 5		
Pulse duration, ns	< 20		
Beam diameter, mm	< 1	< 10	
Beam divergence, mrad	< 4	< 0.4	
Beam quality parameter, M^2	< 1.5	< 2	
Cooling type	conductive		
Operation temperature, °C	- 40 ÷ + 50		
Dimensions (L × W × H), mm	110 × 40 × 22	156 × 40 × 20	120 × 45 × 22
Weight, kg	< 0.20	< 0.25	< 0.60

Laser generates Gaussian beam on TEM_{00} mode with divergence of < 4 mrad

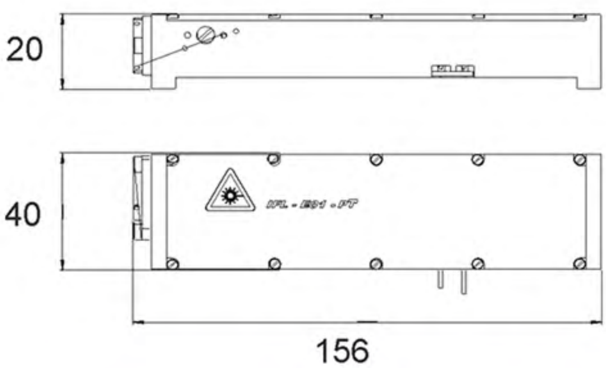


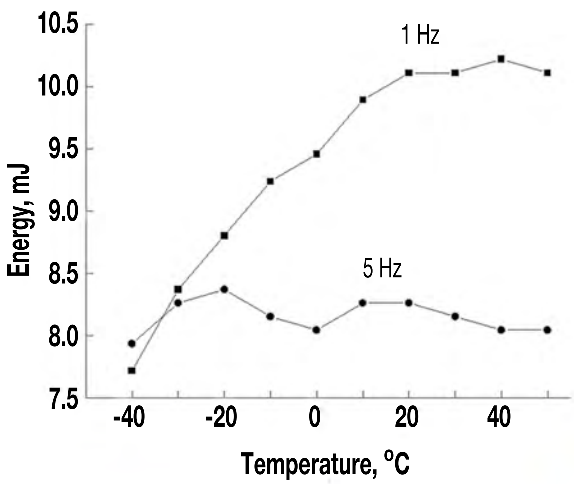
Temporal profile of IFL-E85-P laser beam



Main features:

- lasers are resistant to vibrations up to 75 g
- do not require forced cooling
- hermetic housing





SCIENTIFIC CENTER "OPTICAL REMOTE PROBING"

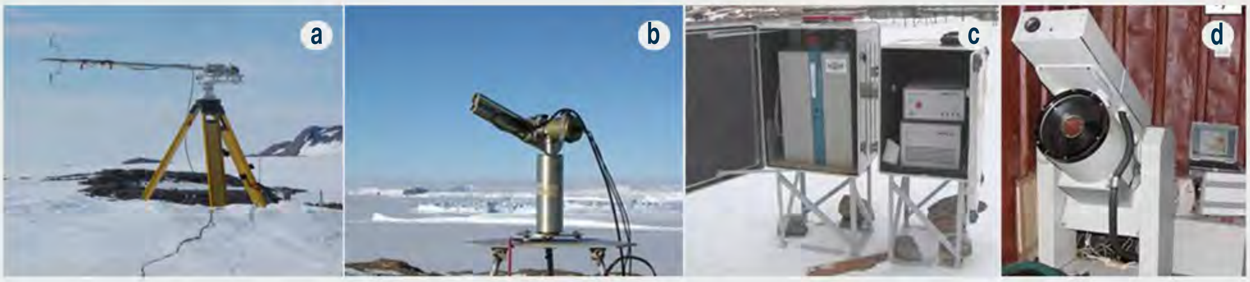
Scientific directions:

- theory of radiation transfer in inhomogeneous and stochastic scattering media; image transfer in scattering media
- development of the methodology for complex remote ground and satellite monitoring of the atmosphere and the surface of the earth
- investigations of snow, glaciers and open water surface of Antarctica aimed to solving problems of climatology and control of large-scale pollution movement
- monitoring of cross-border movement of pollutions in the region of Belarus
- development of optical remote sensing equipment for atmospheric aerosol, gas impurities and underlying surface
- investigations of light scattering and absorption by individual particles and ordered dispersed structures for solving problems of optimization of the characteristics of photonic crystals, liquid crystals and optical coatings and solar cells

Conplex ground and satellite monitoring of the atmosphere and earth's surface in Antarctica

“Mount Vechernyaya” is a seasonal Belarusian Antarctic research station located in the east of Vechernaya mountain (272 m), on the coast of the Cosmonaut Sea.

A multi-functional instrument complex for remote monitoring of the atmosphere and the earth's surface, including multi-wave lidars and solar spectrophotometers was created and put into operation for the first time in the research station.



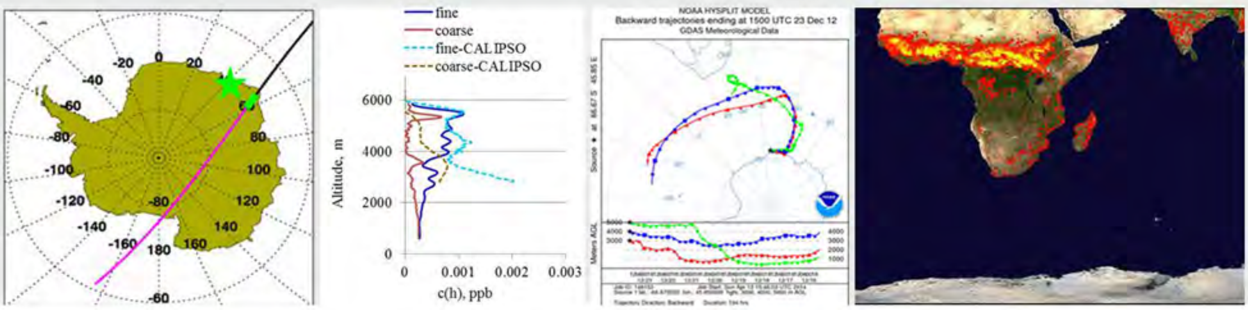
Equipment for measuring aerosol and underlying surface characteristics:

a - spectral albedometer; b - multi-wave scanning solar radiometer;

c - double-wave lidar; d - multi-wave Raman lidar

Complex ground-based and satellite, multi-wave lidar and radiometric investigations of tropospheric aerosol were conducted for the first time in Antarctica. Large-scale movement of fire smoke from South Africa was registered in the area of location of Belarusian Antarctic Expedition (BAE).

Complex lidar and radiometric experiment (“Mount Vechernyaya”, 23.12.2012)



Two-channel spectral albedometer “AS-2A”

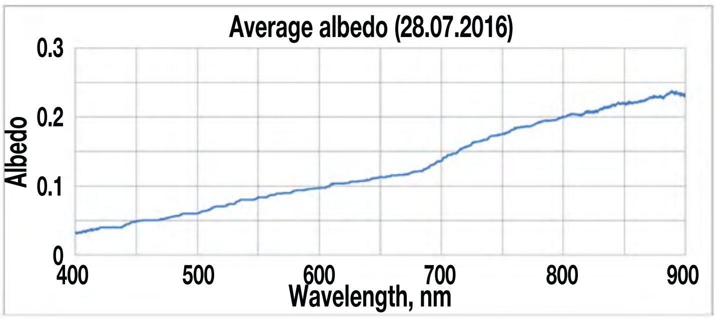
The two-channel spectral albedometer is designed for observing the diffuse reflection (albedo) spectra and the brightness of the earth’s surface. “AS-2A” albedometer consists of a registration, controlling and receiving modules. When measuring the albedo of the earth’s surface the receiving platform of the registration module of channel 1 is located horizontally above the earth’s surface. Photosensors at two surfaces of white scattering platform register the incident and reflected from the surface solar radiation.

Surface brightness is registered in channel 2 with a separate photosensor. The measurements are calibrated according to the intensity of the solar radiation scattered by the white platform.

To increase the number of observation points in automatic mode, the registration modules can be combined into a group of up to 3 samples with a single control center. Albedometer has a manual operation mode with single registration module, while the mobility of observations increases.

Technical parameters:

- observation field — 2π steradian
- spectral range — 350 - 900 nm
- spectral smoothing — by choice
- number of observation points in automatic mode — 3
- distance between observation points in automatic mode — up to 100 m



Container-type lidar “POLYUS”

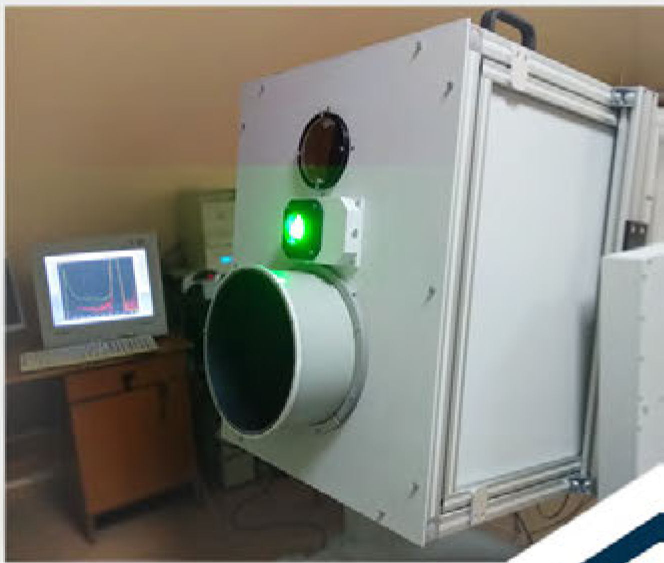
Automated container-type multi-wavelength polarization Raman lidar “POLYUS” is designed for measuring the height profiles of optical properties of aerosol and clouds in the spectral range of 355 – 1064 nm, concentrations of aerosol fractions and identification of the phase composition of clouds. Lidar “POLYUS” measures back-scattering signals at 355, 532 and 1064 nm wavelengths, as well as the depolarized component of the lidar signal at 532 nm in day and night time. In night time the lidar provides measurements of Raman scattering signals with atmospheric nitrogen at the wavelengths of 387 and 607 nm. Atmospheric probing is carried out at the distance of up to 15 km along vertical and inclined routes.

Lidar consists of the following main functional blocks:

- emitter – diode-pumped YAG laser
- small receiving lens of the near-field registration system
- large receiving lens of the far-field registration system
- receiving unit of the of the near-field registration system
- receiving unit of the far-field registration system
- power supply of the laser
- thermal control system
- control PC

Lidar application area:

Lidar will be used to measure atmospheric aerosol parameters in Belarus Antarctic station “Mount Vechernaya” in East Antarctica (67.6600 S, 46.158 E).



SCIENTIFIC CENTER FOR LASER TECHNOLOGY TESTING

In compliance with the instructions of the President of the Republic of Belarus from 08.07.1999 (Protocol No. 9) and the Council of Ministers of the Republic of Belarus from 03.11.1999 No. 05/540-220, with the aim of creating a national system of metrological support of the Republic of Belarus in laser technology and optics, in the Institute of Physics of the National Academy of Sciences of Belarus the Research and Testing Laboratory of Laser Technology (RTLLT) was established in 2000, which was responsible for metrological support of laser and optoelectronic equipment developed, designed and used in the country.

With the Decree of the Presidium of the National Academy of Sciences of Belarus No. 118 from 18.10.2001, the Laboratory was certified as a Center for collective use.

According to the Joint order of the National Academy of Sciences of Belarus and State Committee for Standardization of the Republic of Belarus from 8.08.2003 No. 50/113 the status of Scientific Metrological Center for measurements of parameters and characteristics of laser-optical technology was given to the Institute of Physics of NAS of Belarus, and the functions of the Center were assigned to RTLLT. With the decision of the Customs Union Commission No. 620 from 07.04.2011 the laboratory was included in the Register of agencies for certification and testing laboratories (centers) of the Customs Union that check products for quality conformance with the requirements of Technical regulations of the Customs Union.

In January 2015, the Laboratory was transformed into the Scientific Center for Laser Technology Testing (CLTT) of the Institute of Physics of NAS of Belarus.

The Center is accredited by the Belarusian State Accreditation Center for conformance with the requirements of ISO / IEC 17025, IDT as a test laboratory (accreditation certificate BY / 112 1.1790 is valid until 01.08.2021) and as a calibration laboratory (accreditation certificate BY / 112 02.5.0.0013).

АТТЕСТАТ АККРЕДИТАЦИИ
CERTIFICATE OF ACCREDITATION

Регистрационный номер: BY/112 02.5.0.0013 от 11.07.2005

подтверждает, что

центр испытаний лазерной техники
Государственного научного учреждения "Институт физики имени Б.И.Степанова Национальной академии наук Беларуси"
пр. Независимости, 68, 220072, г. Минск

соответствует критериям
Национальной системы аккредитации Республики Беларусь и аккредитован на соответствие требованиям
СТБ ИСО/МЭК 17025
Область аккредитации определена приложением к настоящему аттестату аккредитации

Срок действия
аттестата аккредитации: с 11 июля 2015 г. до 11 июля 2020 г.

Руководитель Национального органа по аккредитации Республики Беларусь - директор Государственного предприятия "БГЦА" Т.А. Николаева

МП

АТТЕСТАТ АККРЕДИТАЦИИ
CERTIFICATE OF ACCREDITATION

Регистрационный номер: BY/112 1.1790 от 01.08.2016 г.

подтверждает, что

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Национальной системы аккредитации Республики Беларусь и аккредитована на соответствие требованиям
СТБ ИСО/МЭК 17025-2007
Область аккредитации определена приложением к настоящему аттестату аккредитации

Срок действия
аттестата аккредитации: с 1 августа 2016 г. до 1 августа 2021 г.

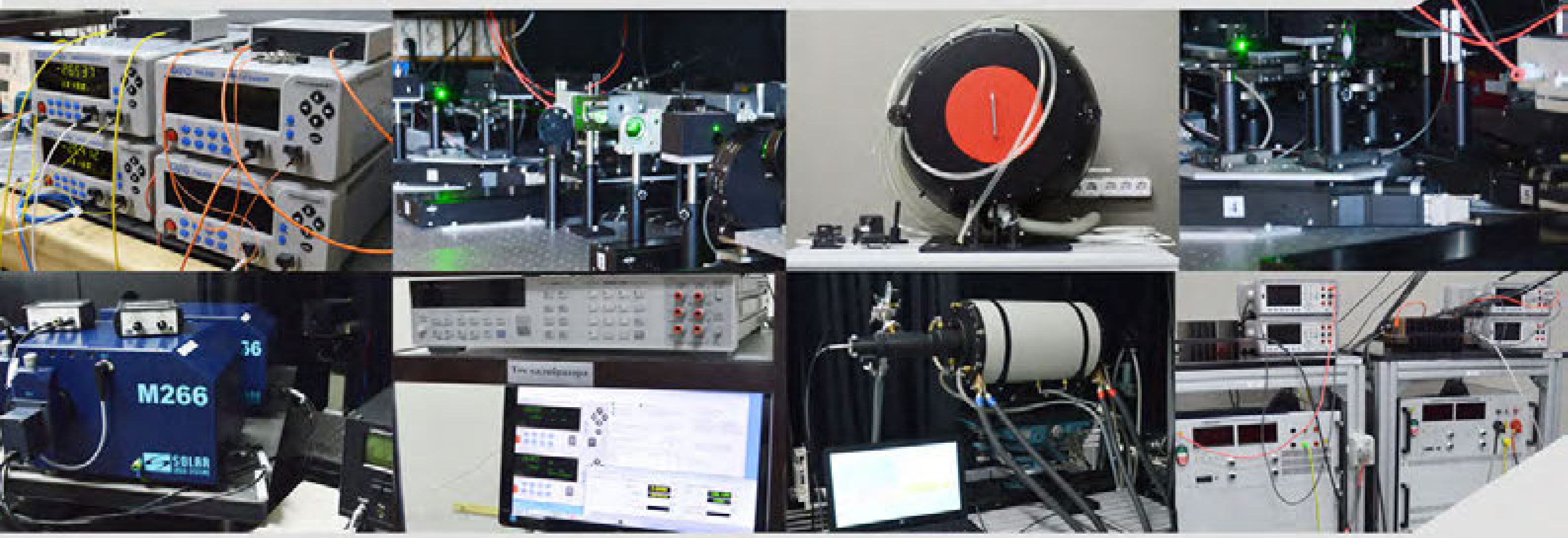
г. Минск, 1 августа 2016 г.

Руководитель Национального органа по аккредитации Республики Беларусь - директор Государственного предприятия "БГЦА" Т.А. Николаева

МП

As a result of joint activities of the Belarusian State Institute of Metrology and CLTT, the national system of metrological support of the Republic of Belarus in laser technology and optics has been created, successfully operates and develops. The system is based on:

- national etalons of physical quantities with corresponding verification schemes used in optics, laser and optoelectronic technology (together with the Belarusian State Institute of Metrology 8 national references of values were created, 4 references are operated in CLTT).
- high precision setups for measurements of characteristics of optical radiation and metrological control (verification, calibration) of measuring instruments (MI) (17 high-precision setups have been created and operated in CLTT)
- state standards that are identical to international standards (65 state standards of the Republic of Belarus in laser technology and optics have been prepared and put into operation in the CLTT with the State Committee for Standartization Decrees)
- programs and methods for metrological certification of etalons, measuring and calibration (verification) installations, methods of measurements and calibration (verification) of measuring tools, included in the Uniformity Measurement System of the Republic of Belarus in laser and optoelectronic technology (more than 80 methods have been developed in CLTT)
- accredited calibration, verification and testing laboratories



National etalon
for average laser pulse power & laser radiation energy units

The national etalon for average laser pulse power and laser radiation (LR) energy units is intended for reproduction and storage in the spectral range from 0.3 to 10.6 microns of units of average laser pulse power and LR energy in the ranges from 10^{-9} up to 2 W and from 10^{-7} up to 1J, respectively, as well as for transmitting the units of average power at the wavelengths of 0.532; 0.808; 1.064 and 10,6 microns and LR energy at the wavelengths of 0,532; 0,808; 1,064 microns to the lower-level etalons, calibration setups and operating measuring tools (MT).

Advantages comparing to world analogues:

- created etalon exceeds the etalons of some international centers in such characteristics as dynamic range and standard uncertainty
- the etalon allows one to reproduce, store and transmit both the average power unit and the LR energy (etalons of some international metrological centers do not reproduce the LR energy unit)
- the usage of electro-optical shutters based on the Pokkels effect in the etalon provides the acquisition of rectangular LR pulses with a repetition frequency up to 1 MHz and duration from 1 μs up to 10 s, consequently the uncertainty of reproduction of LR energy is significantly reduced

Economic efficiency, contribution to solving key social economic problems:

- the etalon will allow to improve calibration of working references and MT in Belarus, which will serve as a basis for creating subsequent levels of the verification scheme
- calibration of MT will put it on a new qualitative level – it will have confirmation of compliance with standards and technical conditions
- etalon exploitation is aimed for the support of metrological needs of departments and organizations using laser technology and, thus, acquires national and social significance

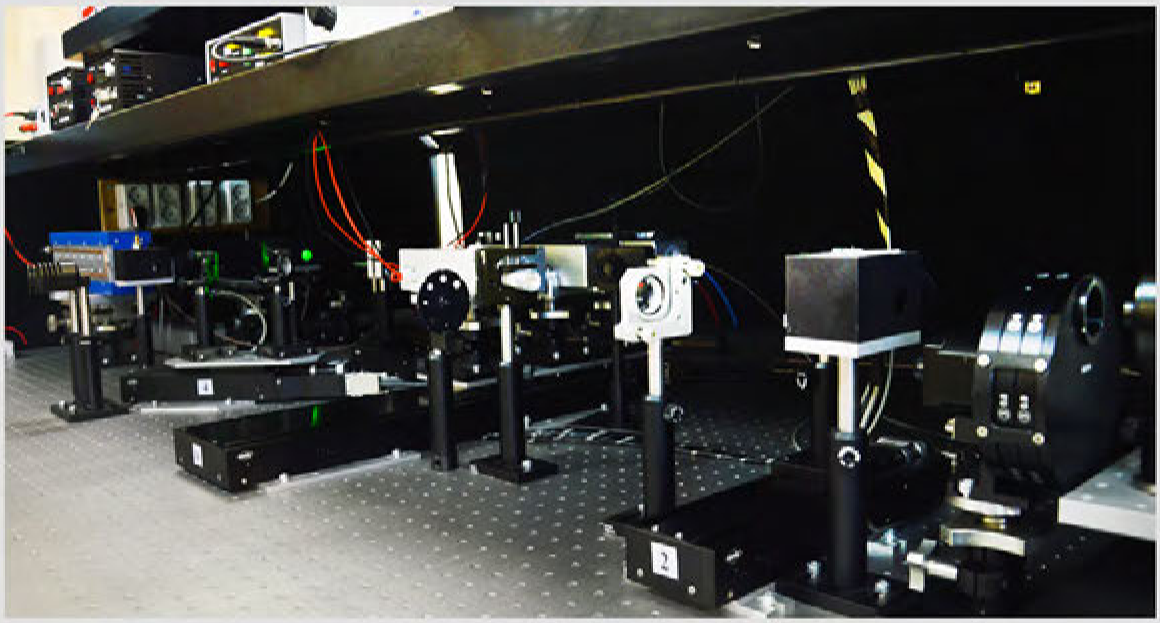
Competitiveness:

Currently in the world there are several tens of thousands of MT of power and LR energy that need constant calibration. Metrological characteristics of the created etalon, corresponding to the world level, allow one to participate in international comparisons, thereby increasing its competitiveness in the foreign market.

In Belarus, the total number of MT of average power and LR energy is estimated at more than 1000 devices. The cost of metrological works in other countries is rather high and requires large currency expenses. Metrological works on the created etalon will exclude the need for foreign metrological centers and provide savings on import substitution.

Application area:

- energy-efficient technologies and equipment
- robotics, intelligent control systems
- new multifunctional materials, special materials with specified properties, optoelectronics and optical systems, electronic instrumentation technologies, microelectronics, radio-electronics
- technologies of prevention, diagnostics and treatment of diseases, rehabilitation technologies, medical biotechnologies, diagnostic agents and test systems, medical equipment, nanotechnologies, information aviation and space technologies, tools of technical and cryptographic protection of information, technologies and systems of electronic identification
- prospective tools and technologies for national security and defense



National etalon for average power, attenuation & wavelength of optical radiation units for fiber-optic communication & information transmission systems

The etalon for average power, attenuation and wavelength of optical radiation units for fiber-optic communication and information transmission systems (FOTS) is intended for:

- ensuring the uniformity of measurements in the spectral range from 650 to 1700 nm of average optical radiation power in the range from 1×10^{-11} to 1×10^{-2} W
- attenuation of optical radiation in the FOTS in the range from 0.05 to 60.00 dB and the wavelength of optical radiation
- reproduction and transmission of the size of units of the specified values at fixed wavelengths of 655, 852, 1309, 1489, 1548 and 1627 nm to lower-level etalons and high-precision operating measuring tools (MT) that are used in the construction, installation and putting into operation of fiber-optic lines.

The etalon was approved as a National etalon with the Decree of the State Committee for Standartization No. 1 from 16.01.2015 and included in the Register of national etalons of the Republic of Belarus with number NE 25-15.

Advantages comparing to world analogues:

international comparisons in the framework of the project of the Organization of cooperation of state metrological institutions of Central and Eastern Europe (KOOMET) COOMET.PR-S8, aimed to establish the degree of equivalence of national etalons of the optical radiation wavelength unit in such countries as Russia, Belarus, Germany, China, Brazil, South Africa and Egypt, showed that the accuracy characteristics of measurements at reproducing the optical radiation wavelength on the etalon are better than similar characteristics of the etalons of the countries that participated in the comparisons.

Economical effectiveness:

as a result of creating the etalon, various fiber-optic devices are checked and their characteristics are measured. It improves the quality of optoelectronic goods for FOTS produced and used in the Republic of Belarus, increases its competitiveness in the domestic and foreign markets significantly reduces costs by reducing the cost of measurements outside the Republic Belarus. Metrological support of FOTS is the necessary element of the development of Belarus as an IT country and contributes to the information security of the Republic of Belarus.

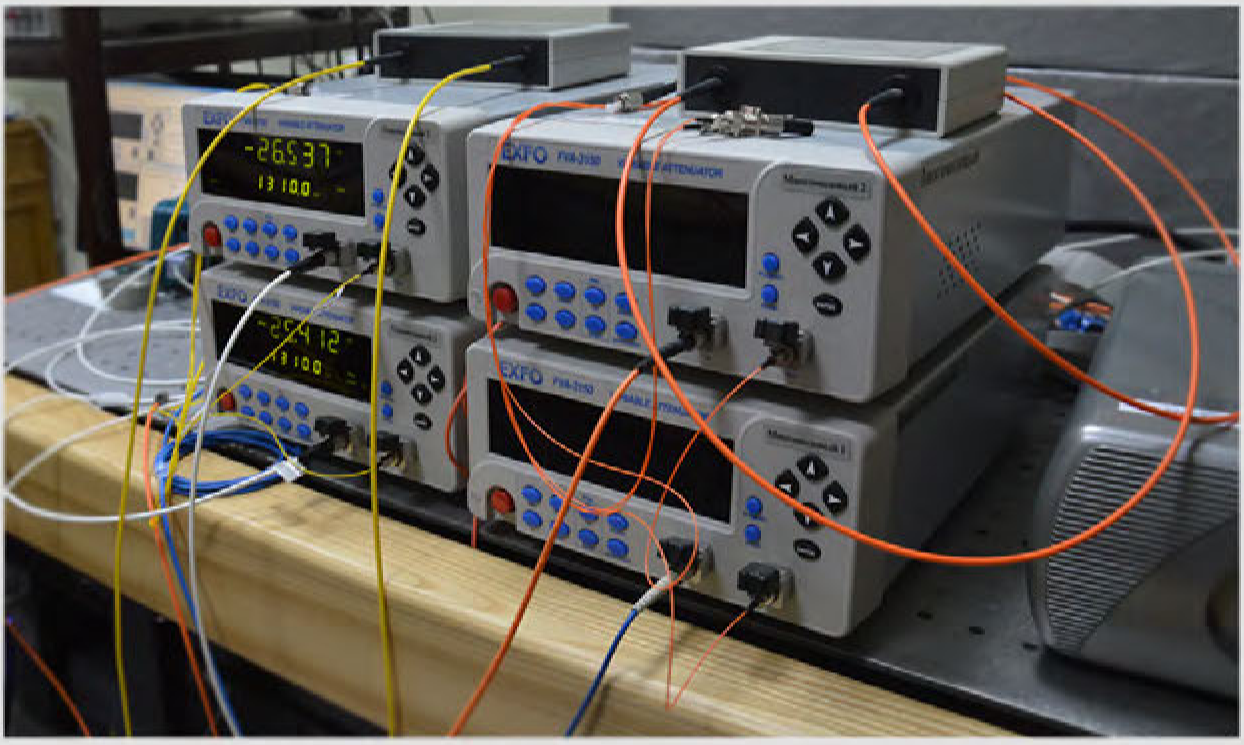
Competitiveness:

Due to the rapid development of FOTS, which are the main direction of growth of telecommunication systems, there are several hundred thousands of MT for average power, attenuation and wavelength of optical radiation in the FOTS. Metrological characteristics of the national etalon NE 25-15, corresponding to the world level, allow one to participate in international comparisons, thereby increasing its competitiveness in the foreign market.

The metrological base of the Republic of Belarus in the field of measurement of FOTS parameters, the most important of which are power and wavelength of optical radiation, attenuation of optical radiation power in an optical fiber, includes more than 500 optical testers, optical reflectometers and spectrum analyzers. The cost of calibration (verification) on the created etalon is significantly lower than the calibration (verification) of one unit of these tools in the All-Russian Research Institute for Optical and Physical Measurements (ARRIOPM) (Moscow), which allows the certification of the majority of existing in the Republic MT with significantly lower costs.

Application area:

- information and communication technologies
- communication
- national security and defense
- protection of the population and territories from emergency situations



National etalon for polarization mode dispersion unit in optical fiber

National etalon for polarization mode dispersion unit in optical fiber designed to ensure the uniformity of measurements of the polarization mode dispersion (PMD) in the range from 0.005 to 120.0 ps, storing the size of the PMD unit in optical fiber, reproducing and transmitting the specified unit value to lower-level references and high-precision operating measuring tools (MT) used in the construction, installation and commissioning of fiber-optic communication lines.

Advantages comparing to world analogues:

- the etalon has metrological characteristics meeting the requirements of international standards
- the accuracy characteristics of the etalon are 1.5 times better than analogical characteristics of SS 185-2010 etalon created in ARRIOPM, Russia

Economic efficiency:

- combination of etalon tools in accordance with the state verification scheme into a unique national etalon with optimization of the number of links in the verification scheme
- increasing the accuracy of transmitting the PMD unit in the lines and elements of fiber-optic systems for transmission of information (FOTS)
- creation of a system of metrological support for PMD measurements in high-speed FOTS with spectral compaction
- possibility of upgrading of the existing FOTS in order to increase the capacity of communication lines

The exploitation of the etalon is aimed to support the metrological needs of departments and organizations that use FOTS, so it acquires national and social significance.

Compatibility:

Due to the rapid development of FOTS, which are the main direction of growth of telecommunication systems, there are several hundred thousands of MT for PMD. Metrological characteristics of the National etalon, corresponding to the world level, allow one to participate in international comparisons, thereby increasing its competitiveness in the foreign market.

The metrological base of the Republic of Belarus in the field of PMD measurement in optical fiber and FOTS elements includes more than 100 MT. The cost of calibration (verification) on the created reference is significantly lower than the calibration (verification) of one unit of these tools in the All-Russian Research Institute for Optical and Physical Measurements (ARRIOPM) (Moscow), which allows the certification of the majority of existing in the Republic of Belarus MT with significantly lower costs.

Application area:

- information and communication technologies
- communication, optoelectronics and optical systems
- national security and defense
- protection of the population and territories from emergency situations

National etalon for units of spectral brightness, spectral radiance & radiation intensity in the wavelength range from 0.3 to 3.0 µm

National etalon for units of spectral brightness, spectral radiance and radiation intensity in the wavelength range from 0.3 to 3.0 µm (hereinafter – etalon) is designed to reproduce, store, and transmit the size of the corresponding units to operating etalons and other measuring tools (MT) used for calibration, diagnostics and measurements of optical characteristics of optical radiation sources and receivers used in industry, research and instrumentation, agricultural technologies, medicine and health care, information and communication technologies and aerospace technologies.

Advantages comparing to world analogues:

- design of the etalon makes it possible to measure spectral radiance and radiation intensity at a distance between the receiver and the radiation source of less than 200 mm, which is important for measuring of optical characteristics of LEDs and some types of reference lamps
- the etalon allows one to measure the spatial distribution of radiation intensity and spectral radiance of small-sized radiation sources, including light emitting ones
- system of thermal stabilization of the model of a high-temperature black body provides its cooling with the error of 0.2 °C, which allows to improve the metrological characteristics of the etalon and increase its working life time

Economic efficiency:

The exploitation of the etalon is aimed to support the metrological needs of departments and organizations that use or design spectral radiometric instruments, so it acquires national and social significance.

Competitiveness:

Currently there are hundreds of thousands of radiometers, spectrometers, spectral radiometers and spectral radiometer systems in operation worldwide which need constant calibration (verification). Metrological characteristics of the National etalon, corresponding to the world level, allow the participation in international comparisons, thereby increasing its competitiveness in the foreign market.

The metrological base of the Republic of Belarus in the field of measurements of optical radiation radiometric and spectral radiometric characteristics includes more than 400 radiometers, 200 spectrometers, spectral radiometers and spectral radiometer systems. The cost of calibration (verification) in other countries is rather high and needs currency expenses. The cost of calibration (verification) of one reference lamp in the Institute of Physics of NAS of Belarus is much lower.

Application areas:

- energy-efficient technologies and equipment
- agriculture industry technologies and production
- processing of agricultural products
- food production
- robotics
- intelligent control systems
- new multifunctional materials
- special materials with specified properties
- optoelectronics and optical systems
- electronic instrumentation technologies
- microelectronics, radio electronics
- prevention technologies
- diagnosis and treatment of diseases
- rehabilitation technologies
- pharmaceutical technology
- medical biotechnology
- medicines
- diagnostic chemistry and test systems
- medical equipment
- hygienic assessment and normalization of environmental factors
- minimization of risks to human health
- nanotechnologies
- biotechnologies in agricultural production and food industry
- information, aviation and space technologies
- tools for technical and cryptographic protection of information
- electronic identification technologies and systems
- sustainable use of natural resources and environmental protection
- solar power industry
- perspective tools and technologies for national security and defense
- protection of population and territories from emergency situations

SCIENTIFIC SENTER FOR ANALYTICAL & SPECTRAL MEASUREMENTS

The main investigation areas are:

- comprehensive spectroscopic measurements and investigation of substances in various phase states (absorption, transmission, and reflection in UV-, visible and IR-spectrum regions spectroscopy, EPR-spectroscopy, RS-spectroscopy and luminescent spectroscopy)
- C, H, N, O, S – analysis of natural and synthetic materials
- determination of concentration of ions of various metals in water, food, medicines, animal products, crop production and other materials
- acquisition of new knowledge about the structure of molecules and molecular complexes
- development of methodological foundations for molecular and atomic spectral analysis of metals, alloys, cosmetics, medicines, etc.
- consultations in spectroscopic investigations and interpretation of their results
- seminars on the application of modern analytical methods for substance research

SCIENTIFIC SENTER FOR ANALYTICAL AND SPECTRAL MEASUREMENTS
is accredited for compliance with the requirements of ISO / IEC 17025-2007, IDT

НАЦИОНАЛЬНАЯ СИСТЕМА АККРЕДИТАЦИИ РЕСПУБЛИКИ БЕЛАРУСЬ
ОРГАН ПО АККРЕДИТАЦИИ РЕСПУБЛИКИ БЕЛАРУСЬ

АТТЕСТАТ АККРЕДИТАЦИИ
CERTIFICATE OF ACCREDITATION

Регистрационный номер: BY/112 1.0480 от 27.03.2006 г.

подтверждает, что

центр аналитических и спектральных измерений
Государственного научного учреждения
"Институт физики имени Б.И.Степанова
Национальной академии наук Беларуси"
пр. Независимости, 68, 220072, г. Минск

соответствует требованиям
Национальной системы аккредитации Республики Беларусь и
аккредитован(а) на соответствие
СТБ ИСО/МЭК 17025-2007 (ISO/IEC 17025:2005, IDT)
в области аккредитации, прилагаемой к настоящему
аттестату аккредитации и являющейся его неотъемлемой частью.

Срок действия
аттестата аккредитации: с 22 августа 2019 г. до 22 августа 2024 г.

г. Минск *20 августа 2019 г.*

Руководитель органа
по аккредитации Республики Беларусь -
директор государственного
предприятия "БГЦА" Т.А.Николаева

МП

(актуальном) статусе аттестата аккредитации и действительной (актуальной) области аккредитации содержатся в реестре Национальной системы аккредитации Республики Беларусь (www.bsca.by).

IR-Fourier spectrometer NEXUS with IR-microscope Continuum

Purpose:

measurement of IR absorption and reflection spectra, investigation of the structure of substances, determination of admixtures, control of the purity of substances in various aggregate states, multicomponent gas mixtures.

Technical characteristics of the spectrometer:

- spectral range	from 6400 to 50 cm^{-1}
- resolution	higher than 0.1 cm^{-1}

Technical characteristics of the console:

- mirror reflection	20°, 70° & 80°
- diffuse reflection	
- ATR	
- for micro-samples	

Technical characteristics of the microscope:

- spectral range	from 4000 to 650 cm^{-1}
- detector	MCTA
- lenses	15^{x} (IR)
	10^{x}, 20^{x}, 40^{x} (visible)

Spectrometer series is untended for:

determination of elemental composition, as well as the concentration of various metal ions in water, food, animal products, crop production and other materials

ICP spectrometer

Atomic emission inductively coupled plasma spectrometer IRIS Intrepid II, model XDL

Technical parameters:

- spectral range	from 165 to 1050 nm
- detection limits	
As, Se	0,06 μg/dm^3
Be, Cd, Sr	0,21 μg/dm^3
Ba, Ca, Co, Cr, Cu, Mg, Mn, Mo, Na	0,11 μg/dm^3

ICP spectrometer with mass-spectroscopy detector

Technical parameters:

- detection limits for some isotopes according to 3 sigma criterion, (ppt):

^{7}Li - 0.005	^{55}Mn - 0.4	^{59}Co < 1
^{23}Na - 0.3	^{56}Fe - 0.3	^{60}Ni < 10
^{24}Mg - 0.01	^{9}Be < 1	^{65}Cu < 5
^{39}K - 0.8;	^{27}Al < 4	^{66}Zn < 5
^{40}Ca - 0.7	^{51}V < 1	^{75}As < 5
^{52}Cr - 0.1	^{52}Cr < 5	^{78}Se < 100

Atomic-absorption spectrometer Spectra AA 220/FS

Technical parameters:

- spectral range	from 200 to 850 nm
- detection limits	
Be, Cd	0.0001 mg/dm^3
As	0.005 mg/dm^3
Co, Cr, Cu, Mn, Mo, Ni, Pb, Zn	0.001 μg/dm^3
Fe	0.04 mg/dm^3
Al, Ba	0.01 mg/dm^3

C, H, N, O, S-analyzer VARIO EL III-ELEMENTAR

Purpose:

- determination of carbon, hydrogen, nitrogen, oxygen and sulfur in organic samples
- determination of the quality of medicines, medicinal raw materials
- substance identification

Technical parameters:

- burning temperature	1150°C
- carrier gas	helium
- quantity of substance	from 0.03 to 30 mg
- accuracy	0.1 %
- analysis speed	from 12 to 15 min

Spectrophotometer CARY-500

Purpose:

measurement of absorption, transmission and reflection spectra, investigation of the structure, composition and admixtures of various substances, determination of the activator concentration in solutions and glasses.

Technical parameters:

- spectral range
  from 190 to 3300 nm
- programmed slit with step
  from 0.01 to 5 nm (UV, visible)
  from 0.04 to 20 nm (IR)
- maximal scanning speed
  up to 2000 nm/min (UV, visible)
  up to 8000 nm/min (IR)
- wavelengths setting error
  ± 0.1 nm (UV, visible)
  ± 0.4 nm (IR)

Mobile laser spectrum analyzer

Mobile laser spectrum analyzer (MLSA) is designed for qualitative and quantitative elemental analysis of various solid samples – metals, alloys, ores, ceramics, semiconductors and crystals, soils, ect. The basis of the analysis is atomic emission spectroscopy of laser-induced plasma created near the sample surface by the focused high-density laser beam (the method is known better as LIBS).

Distinctive features and advantages:

The device is suitable both for research and industrial applications (analysis in metallurgy, mechanical engineering, etc.).

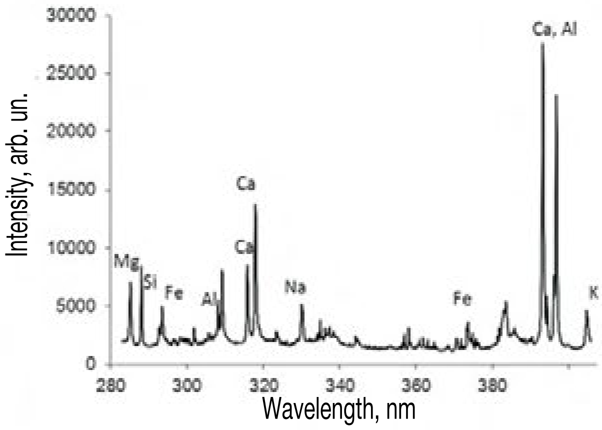
Customization.

Optimization of software and measurement methods according to the customer's tasks.

Technical parameters:

2-channel solid-state diode-pumped laser:

- wavelength	1064 nm
- max. pulse energy	63 mJ
- max. pulse repetition rate	10 Hz
- pulse half-width	10 ns
- applied area	< 2 mm
- continuous operation	8 h
- weight	17 kg
- max. power consumption	< 1000 W



Mobile laser spectrum analyzer has calibration certificate # BY 01 257-50 from 07/07/2014.

Registration system:

- diffraction spectrometer + CCD
- software for quantitative and qualitative analysis

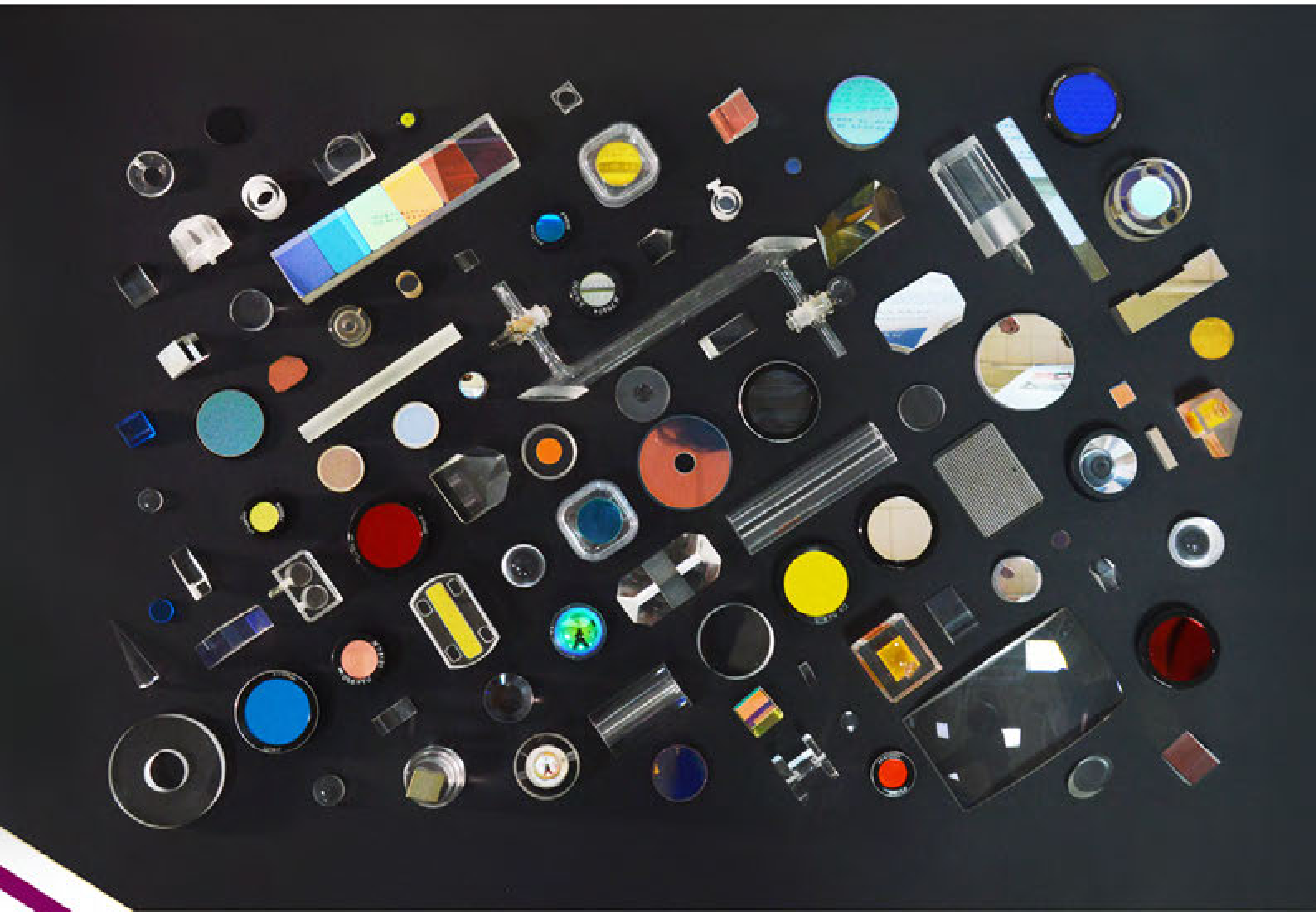
- spectral range	200 – 1000 nm
- spectral resolution	0.014 nm

SCIENTIFIC & PRODUCTION CENTER FOR OPTOELECTRONIC INSTRUMENTATION

The Center is specialized on manufacturing of high-quality precision optical components and optical-mechanical units using various optical materials, including quartz glass, glass-ceramics Sitall and ZERODUR, crystals of Nd:YAG alumoittrium garnet, leucosapphire (Al_2O_3), CaF_2, LiF, spinel and others.

Scientific and Production Center for Optoelectronic Instrumentation produces:

- lens optics
- optical filters, dielectric mirrors, beam splitters, antireflective coatings
- laser optics
- achromats, triplets, beam expanders
- polarizing optics
- crystal optics
- micro-optics
- high-precision windows and wedges
- optical elements and mechanical units according to customer 's drawings



Services:

- adjustment of optical systems and devices
- quality control of assembling of lenses and telescopic attachments
- metrological quality control of the optical surface
- measuring and controlling the profile and surface roughness

Technical characteristics can be achieved:

- details diameter	5 – 250 mm
- surface cleanliness	class 2
- surface roughness	up to 2 Å
- surface accuracy	N = 0.2
- linear dimensions tolerance	± 0.01 mm
- angular dimensions tolerance	up to ± 1''
- parallelism tolerance	± 1''
- spectral range of applied coatings	360 – 2000 nm

Quality control is performed at all stages of production using such modern measurement tools as ZIGO GPI XP interferometer (working diameter up to 150 mm), MÖLLER-WEDEL Goniomat M, goniometer, SURFCOM CREST profilometer, PHOTON RT spectrophotometer and others.
Measurement protocol is provided for all optical components.
The production site is equipped with modern CNC metal-processing centers that allow high-precision turning and milling.
We are ready to work with small orders (less than 100 units). The Center provides services for making 3D models of complex parts, search and design of constructive solutions for complex parts and devices assembling.

Opportunities of the Center:

Technological process of optical details polishing on 4PD-200 machines

Turning and milling metal-processing center ST-10Y by "HAAS"

CNC milling metal-processing center DM-1 by "HAAS"

Vacuum deposition of optical coatings on Ortus and Aspire setups

Processing of the optical detail blank on the circular grinding machine RSM500A

Technological washing of blanks before deposition of optical coating
in the automatic washing machine USC120 Optimal Technologies

Precision measurements, control and analysis of the profile and surface roughness with ACCRETECH Surfcam Crest profilometer

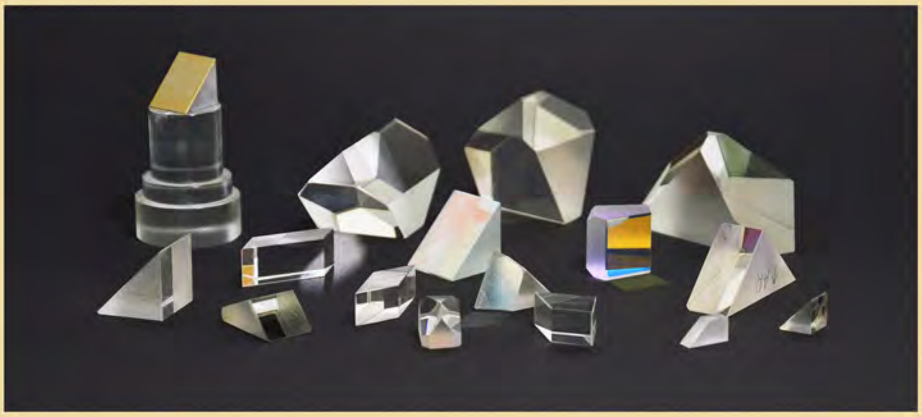
The Center provides services for metrological control of surface quality with registration of the measurement protocol. The control is carried out with a modern high precision automated profilometer ACCRETECH Surfcom Crest Profiler by ZEISS. The device is certified and included in the State Register of Measuring Tools of the Russian Federation.

Distinctive features:

- model with the highest accuracy in its class of equipment
- measuring system is developed on the basis of a highly stable laser interferometer, having an optical fiber – based construction and resolution of 0.31 nm
- Surfcom Crest differs with a dynamic range of resolution coefficients of 42,000,000:1, which means that while measuring the contour profile, both wide range and compact high-precision surfaces can be measured
- control of profile and roughness during a single measurement
- surface topography analysis system
- measurement efficiency by combining two solutions in one measurement unit. One dimension – two reports
- wide measurement range of 200 mm (horizontal movement) and 13 mm (vertical movement)
- motorized drive allows 45° surface inclination for measurement system flexibility

High-precision prisms and prism blocks

- rectangular prisms
- Dove prisms
- pentaprisms
- triple-prism
- complex shape polygonal prisms
- prism blocks



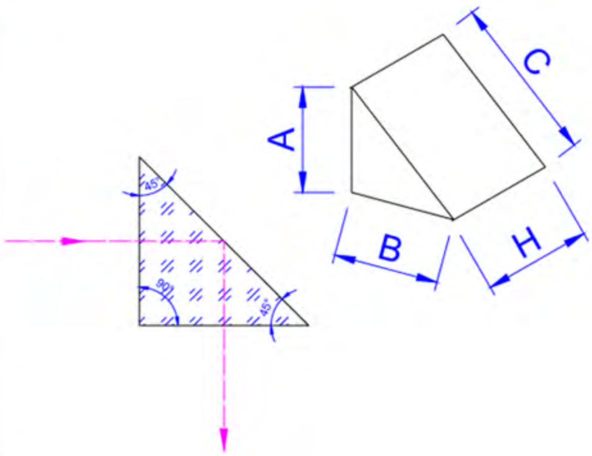
Technical specifications

Dimensions of processed parts, mm	5 – 150
Material	KU-1 or C8
Linear dimensions tolerance, mm	± 0.01
Angular dimensions tolerance	± 0.5''
Pyramidal tolerance	± 1''
Surface cleanliness	class 2
Surface roughness, Å	up to 4
Surface accuracy	N = 0.2
Spectral range of applied coating, nm	360 – 2000

Rectangular prisms

They are used to rotate the optical system by 90° and rotate the image by 180° in the same plane. At putting a beam-splitting coating to the hypotenuse, the prism serves for splitting the beam into two parts.

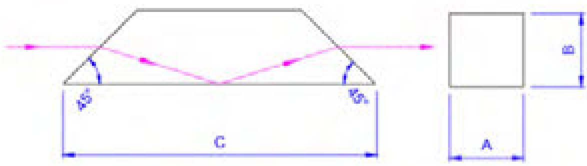
A = B, mm	H, mm	Material	Definition
5	5	C8	RAP5-BK7
5	5	KU-1	RAP5-UVFS
8	8	C8	RAP8-BK7
8	8	KU-1	RAP8-UVFS
10	10	C8	RAP10-BK7
10	10	KU-1	RAP10-UVFS
12.7	12.7	C8	RAP12.7-BK7
12.7	12.7	KU-1	RAP12.7-UVFS
15	15	C8	RAP15-BK7
15	15	KU-1	RAP15-UVFS
25.4	25.4	C8	RAP25.4-BK7
25.4	25.4	KU-1	RAP25.4-UVFS



Dove prisms

This is a reversal prism, which gives a mirror image of the object without changing the direction of the parallel beam passing through it. It can also be used as a retroreflector and image rotation compensator.

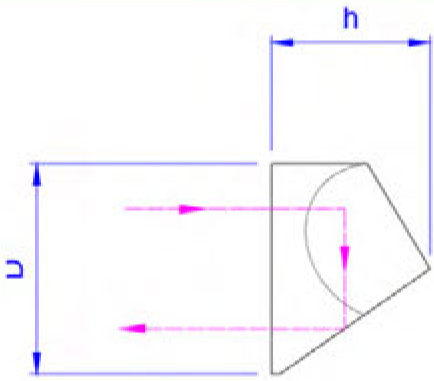
A = B, mm	H, mm	Material	Definition
5	5	C8	DV5-BK7
5	5	KU-1	DV5-UVFS
10	10	C8	DV10-BK7
10	10	KU-1	DV10-UVFS
15	15	C8	DV15-BK7
15	15	KU-1	DV15-UVFS
20	20	C8	DV20-BK7
20	20	KU-1	DV20-UVFS



Trippel-prisms

The prism reflects the beam to the source regardless of its orientation and is used as a retroreflector.

D, mm	h, mm	Material	Definition
8	6.5	C8	RRP8
15	11.5	C8	RRP15
25.4	19	C8	RRP25.4
38	28.5	C8	RRP38
50.8	37.5	C8	RRP50.8



Other types and sizes can also be mutually agreed for production with the customer.



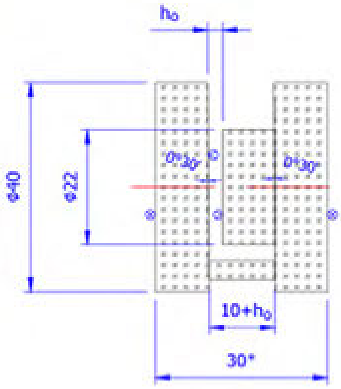
Fabry – Perot etalons

The etalons are used as selective elements of laser resonators for narrowing and rearranging the radiation band, as well as dispersing elements of high-resolution spectral devices. The etalon consists of two quartz plates separated by an air gap. The plates are polished with high flatness (λ / 20) and have a wedge shape to eliminate flares. An intermediate quartz ring is installed between the plates, providing an accurate air gap.

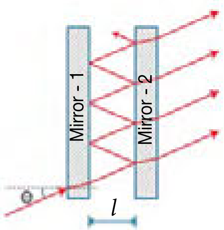
Technical specifications:

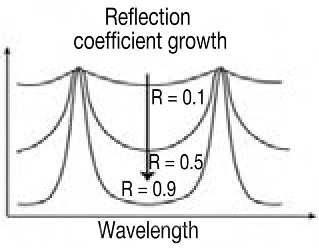
- dimensional accuracy — +0/-0.1 mm
- accuracy of interferometric surfaces — N = 0.1
- surfaces cleanliness — class 2
- non-parallelism in the interferometric gap — ± 1''
- mirrors reflection coefficient — 80 – 85 %

Standard construction



Intensity distribution in the transmitted light depending on interference order:





The width of the dispersion region of Fabry-Perot etalon is determined from the superposition of (m+1)-th order ring for the wavelength and the m-th order ring for the wavelength λ+Δλ: $\Delta\lambda \approx \lambda_2 / 2h_0$

Technical specifications

Definition	Light diameter, mm	Total diameter, mm	Length, mm	Interferometer base h_0, μm	Spectral region, nm
FPE-40-6	20	40	30	6	540 – 700
FPE-40-146	20	40	30	146	540 – 700
FPE-40-2.4	20	40	30	2400	540 – 700

Other parameters and sizes can also be mutually agreed for production with the customer.

Quarter-wave and half-wave phase plates of zero & multiple order

Quarter-wave and half-wave phase plates of zero and multiple order are used to transform the polarization state of a light beam by shifting the phases between two perpendicular polarizing components of incident light.

The quarter - wave plate provides a phase shift of a quarter of the wavelength and changes linear polarization to circular and vice versa.

The half-wave plate creates a phase shift of a half of the wavelength and rotates polarization direction of linearly polarized light.

Technical specifications:

- diameter without armor	10 – 25 mm
- diameter with armor	12.7 – 30.0 mm
- substrate material	monocrystalline quartz
- operating wavelengt	360 – 1700 nm
- surface shape accuracy	N = 0.2
- surface cleanliness	classes 2 – 3
- phase difference tolerance	λ/500

Measurement protocol is provided for all optical components.

High-precision polishing of laser crystals

The following crystalline materials can be used for production of optics:

- Nd:YAG alumoittrium garnet crystals
- leukosapphire (Al_2O_3)
- calcium fluoride CaF_2
- lithium fluoride LiF
- magnesium fluoride MgF_2
- crystalline quartz
- spinel

Technical specifications:

- diameter of details	5 – 50 mm
- surface cleanliness	class 2
- surface roughness	up to 4 Å
- surface accuracy	N = 0.2
- linear dimensions tolerance	± 0.01 mm
- angular dimensions tolerance	up to ± 1''
- parallelism tolerance	± 1''
- applied coatings spectral range	360 – 2000 nm

Configuration of optical components and technical specifications - in accordance with the customer 's requirements.
Measurement protocol is provided for all optical components.

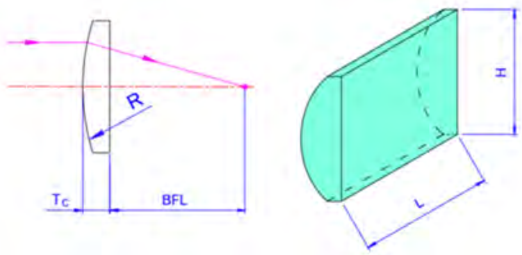
Cylindrical optics

Cylindrical lenses:

- plane-spherical
- flat-concave
- bi-convex
- bi-concave

Cylindrical positive lens focuses the beam only to one coordinate.
Cylindrical negative lens scatters the beam only to one coordinate.

Cylindrical lenses are used to focus light into line for efficient harmonic generation in nonlinear crystals, laser scanners, spectroscopy, dye lasers, acousto-optics and other applications. They are essential for creating a spherical shape - beam emitted by a laser diode, for focusing of beams to linear detectors or entrance slits of the devices.



Lenses are produced with an optical coating for a given spectrum range. The materials of the lens substrate are colorless crown glass and flint glass, quartz glass, CaF_2 crystals and other materials.

Technical parameters:

- dimensional accuracy +0/-0.1 mm
- surface accuracy N = 0.1
- centering accuracy < 1''
- surface purity class 3

Definition for arder	Dimension H × L, mm	Light diameter, mm	Thickness T_C, mm	Focal distance, mm	Material
PCXCYL-1-20-26	20 × 20	18 × 18	6.5	26.5	N-BK7
PCXCYL-2-20-26	20 × 20	18 × 18	4	30	UVFS
PCXCYL-1-20-50	20 × 20	18 × 18	4	50	N-BK7
PCXCYL-2-20-50	20 × 20	18 × 18	4	50	UVFS
PCXCYL-1-20-75	20 × 20	18 × 18	4	75	N-BK7
PCXCYL-2-20-75	20 × 20	18 × 18	4	75	UVFS
PCXCYL-1-20-100	20 × 20	18 × 18	4	99.6	N-BK7
PCXCYL-2-20-100	20 × 20	18 × 18	4	99.6	UVFS
PCXCYL-1-35-150	35 × 35	32 × 32	5	150.8	N-BK7
PCXCYL-2-35-150	35 × 35	32 × 32	5	150.8	UVFS
PCXCYL-1-20-26	20 × 20	18 × 18	3	-26.5	N-BK7
PCXCYL-2-20-26	20 × 20	18 × 18	3	-26.5	UVFS
PCXCYL-1-20-50	20 × 20	18 × 18	3	-50	N-BK7
PCXCYL-2-20-50	20 × 20	18 × 18	3	-50	UVFS

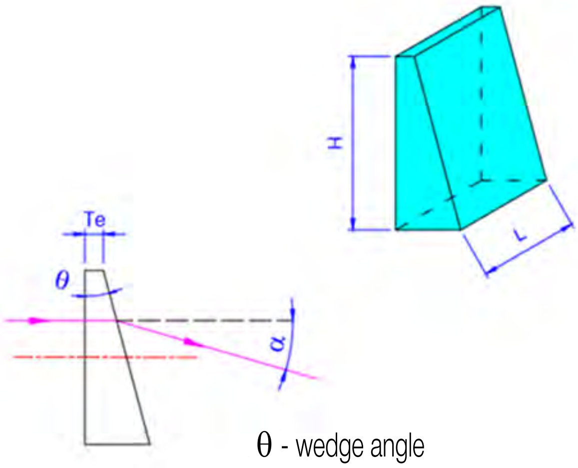
Other parameters and sizes can also be mutually agreed for production with the customer.

Optical wedges

Optical wedges are used to obtain and measure small beam deflection angles, also wedges are useful in the devices, where coherent light is used to eliminate unwanted interference effects that may occur in plane-parallel plates.

Technical specifications:

- dimensional accuracy — +0/-0.1 mm
- angular error — < 30''
- surface accuracy — N = 1
- surface cleanliness — class 3
- substrate material — K-8 (N-BK-7)



θ - wedge angle

α - beam deflection angle

The materials of the lens substrate are colorless crown glass and flint glass, quartz glass, CaF_2 crystals and other materials.

Definition for order	Dimensions H × L, mm	Light diameter, mm	Edge thickness T_e, mm	Wedge angle θ, angl. deg.	Calculated wavelength λ, μm	Beam deflection angle α, angl. deg.
WP-20-0.5	20 × 20	18 × 18	1.5	1° 56'	632.8	0.5°
WP-20-2.0	20 × 20	18 × 18	1.5	3° 52'	632.8	2°
WP-20-4.0	20 × 20	18 × 18	1.5	7° 41'	632.8	4°
WP-20-6.0	20 × 20	18 × 18	1.5	11° 21'	632.8	6°
WP-20-10	20 × 20	18 × 18	1.5	14° 51'	632.8	10°

Other parameters and sizes as well as substrate material can also be mutually agreed for production with the customer.

Spectral range of the applied coatings is 360 – 2000 nm.