



INSTITUTE FOR NUCLEAR PROBLEMS BELARUSIAN STATE UNIVERSITY





Institute associates, May 2016

Institute for Nuclear Problems of Belarusian State University (INP BSU) was founded in October 1986 and currently is the leading belarusian research organization in the area of microworld and nanoworld physics and astrophysics. The Institute is also actively conducting applied research focused on strengthening of the economy and national security of the Republic of Belarus.

Primary research areas:

- nuclear optics and interaction of charged particle beams,
- cosmomicrophysics,
- particle and high energy physics,
- physics of nanostructures and nanoelectromagnetics,
- radiation technology and applied research.

The Institute has about 130 employees (2016), including eight doctors of science and twenty-five Ph.D. Three scientists have academic title Professor.

According to the contract with State Committee on Science and Technology of the Republic of Belarus (SCST) the Institute is responsible for the organizational support for scientific research carried out in the Joint Institute for Nuclear Research (Dubna) with the participation of organizations and institutions of the Republic of Belarus. The institute takes active part in huge international experimental collaborations in the field of high energy physics: CMS, ATLAS, FCC, CLICdp and FCAL.

The scientific school «Nuclear optics» in the field of nuclear physics and elementary particle physics plays active role in the Institute. Founder of scientific school – Professor V.G. Baryshevsky.

The scientific school in the field of particle and high energy physics based on the research of Professor N.M. Shumeiko is actively working.

The scientific school of electrodynamics and electromagnetic-properties of nanostructures is actively developing. The founders of scientific school are Professor S.A. Maksimenko and Professor G.Y. Slepian.

During 2011–2015 the 1151 scientific contributions were published by our scientists including 780 articles, two monographs and five books of proceedings. The 537 of articles were published in peer-reviewed scientific journals and books.

According to the rating of belarusian research organizations based on the scientometric Hirsch index INP BSU takes:

- the third place in list of "Top 25 organizations in Belarus",
- the second place in list of "Universities and research institutions attached to them".

The twelve of INP BSU employees have personal Hirsch index value more than fifteen.

The scientists of INP BSU actively participate in international projects in collaborations with colleagues from institutes and universities from Russia, Poland, Lithuania, Ukraine, Belgium, France, Switzerland, Germany, Italy, USA, China, Singapore and other countries.

The Institute regularly organizes representative international conferences on nanoelectromagnetics, scintillators and nuclear physics, nuclear instrumentation, microworld physics and material sciences.

The achievements of INP BSU scientists were awarded by numerous government and department awards and grants.

Professor V.G. Baryshevsky was awarded the "Sign of Honor" and F. Skaryna orders, the honorary title "Deserved Scientist of the Republic of Belarus", Diploma of the Council of Ministers, the State Prize in the field of Science and Technology of the Republic of Belarus.

Professor N.M. Shumeiko was awarded the F. Skaryna medal, the Friendship order of Russian Federation, the Honorary Diploma of the Council of Ministers of the Republic of Belarus, the Honorary Diploma of the National Assembly of the Republic of Belarus, the Honorary Diploma of the SCST, the Medal "Excellence in Education of the Republic of Belarus", the academician F.I. Fedorov's Grant of National academy of Sciences of the Republic of Belarus.

Professor V.V. Tikhomirov is the laureate of the State Prize in the field of Science and Technology of the Republic of Belarus and a winner of Belarusian Komsomol Award.

K.G. Batrakov, P.P. Kuzhir, S.A. Maksimenko and G.Y. Slepian were awarded the A.N. Sevchenko's Prize of the Belarusian State University (2011) for the series of works entitled "Electromagnetism of nanostructures".

The title of "Honored Associate of the Belarusian State University" was awarded to V.G. Baryshevsky, S.A. Maksimenko, N.M. Shumeiko, M.A. Baturitsky, S.A. Kuten, V.I. Ivanov, V.V. Tikhomirov, A.S. Lobko.

Professor S.A. Maksimenko was awarded the Honorary Diploma of the Council of Ministers of the Republic of Belarus and the Honorary Diploma of the National Assembly of Belarus.

The Honorary Diploma of the Council of Ministers of the Republic of Belarus awarded to M.V. Korzhik and V.I. Ivanov.

A number of scientists was acknowledged with diplomas and other awards of the Ministry of Education of Belarus, the Belarusian State University and other ministries and departments.

The young scientists of INP BSU are regularly awarded by scholarship of the President of the Republic of Belarus.

The developments of INP BSU are repeatedly awarded by medals and diplomas at various international scientific and technical exhibitions.

Co-authors of the publication of the CMS collaboration (CERN) on the Higgs boson discovery are four members of the Laboratory of Experimental High Energy Physics: A. Fedorov, M. Korzhik, O. Missevitch, R. Zuyeuski and nine associates of the Center for Particle and High Energy Physics: V. Chekhovsky, I. Emeliantchik, A. Litomin, V. Makarenko, V. Mossolov, N. Shumeiko, A. Solin, R. Stefanovitch, J. Suarez Gonzalez. Another scientist of the Center for Particle and High Energy Physics, S. Yanush, is the co-author of the publication of the ATLAS collaboration on the discovery.

The about of 40 international grants and contracts are currently carried out, including three projects of EC Horizon 2020 program and the unique for CIS project EU megagarant "Graphene Flagship".



Director General Professor Sergey Maksimenko
and **Honorary Director** Professor Vladimir Baryshevsky
(INP BSU founder and director in 1986-2012).

MANAGEMENT***Director General***

Professor Sergey Maksimenko

Tel: +(375 17) 200-84-81

Fax: +(375 17) 226 51 24

e-mail: inp-director@inp.bsu.by

***Director for Research***

Professor Alexander Lobko

tel: +(375 17) 328-61-76

e-mail: lobko@inp.bsu.by

***Director for International Collaboration***

Dr.Sci. Julia Fedotova

tel: +(375 17) 233-90-48

e-mail: julia@hep.by

***Director for General Affairs***

Igor Shpakovsky

tel: +(375 17) 200-87-19

e-mail: ish@inp.bsu.by

***Scientific secretary***

Dr. Vladimir Makarenko

tel.: +(375 17) 226-42-21

e-mail: makarenko@inp.bsu.by

***Chief accountant***

Sofia Yukhno

Tel: +(375 17) 226-42-33

e-mail: buh@inp.bsu.by

HIGH-CURRENT ELECTRONICS LABORATORY

**Head of the laboratory**

Pavel Molchanov

Tel: +(375 17) 226-53-23

e-mail:

molchanov@inp.bsu.by**Scientific Leader**

Professor

Vladimir Baryshevsky

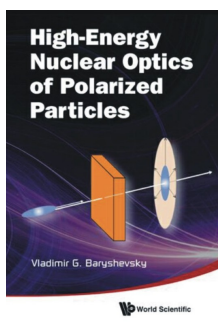
Tel: +(375 17) 328-62-38

e-mail: *bar@inp.bsu.by***Main research areas:**

- high energy nuclear optics of polarized particles and media;
- high-power radiation sources on the basis of high- current and high-voltage particle accelerators;
- generation of high-current and high-voltage pulses by explosively driven magnetic flux compression devices.

High energy nuclear optics of polarized particles and media

The investigations of nuclear-optical activity of matter were initiated by V. Baryshevsky and M. Podgoretsky (1965). Quasi-optical spin rotation of the neutron moving in matter with polarized nuclei, which is a kinematic analog of optical Faraday effect (effect of light polarization plane rotation), was predicted. For particles with spin 1 the quasi-optical birefringence effect could also be observed (Baryshevsky 1992)



Laboratory activities include justification experiments enabling observation of T(CP) odd optical gyrotropy of media and, thus, measuring the T(CP) odd polarizability of atoms and nuclei by high precision optical methods. Measuring of the above physical quantities as well as evaluation of electron (nucleus) electric dipole moments give information about processes within the Plank scale of length with the of solely optical methods, which do not require particle accelerators.



Studies of deuteron birefringence effect at accelerator facilities NICA, GSI, LHC and FCC show great promise. Experiments to measure anomalous magnetic moments of short-lived charm and beauty hyperons by measuring spin rotation angle in bent crystals and spin depolarization value in crystals are proposed for LHC and FCC colliders. Measurement of quadrupole moment of Ω -hyperon and study of spin rotation and depolarization effects for relativistic electrons (positrons) in crystals to evaluate electron (positron) anomalous magnetic moment dependence on the external electric field value can also be performed.

Potential of interaction of an antiproton with a nucleus at extremely low energies (electronvolts) can be evaluated at CERN and GSI antiproton facilities by quasi-optical nuclear precession effect.

High-power radiation sources on the basis of high- current and high-voltage particle accelerators

Development of high-power radiation sources from X-ray and gamma range to optical and microwave ones on the basis of high- current and high-voltage particle accelerators is among laboratory activities. Neutron sources and high-power laser facilities are also within the scope of interests. Experimental prototype of virtual cathode oscillator provides 200 MW peak output power in frequency range from 2.5 to 5 GHz. Operating at voltage as low as 350-450 kV such a microwave source is unique.



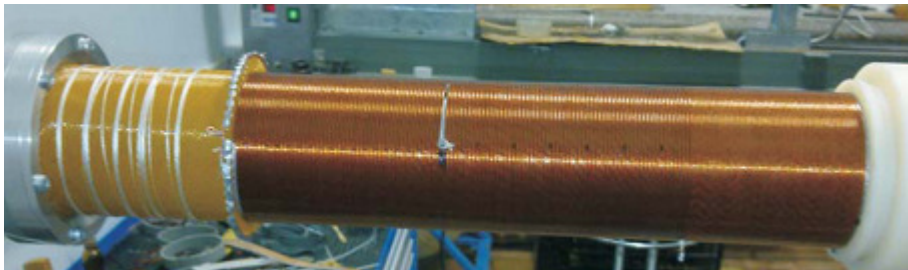
Experimental prototype of virtual cathode oscillator provides 200 MW peak output power in frequency range from 2.5 to 5 GHz

First lasing of volume free electron laser (VFEL) was observed in 2001. A variety of radiation sources providing wide range frequency tuning and high radiation power.

High-power electron beam cumulation in a relativistic vacuum diode with a ring-type cathode is experimentally observed and theoretically interpreted. Coulomb repulsion causes the charged particles emitted by cathode plasma to rush to the region free from the beam. As a result, the accelerated motion of electrons toward the anode comes alongside the radial motion and the high-current beam density could increase multifold on the axis of the relativistic vacuum diode as compared to the average current density in the cathode-anode gap. This effect enables getting high current density electron beams (up to 1.2 kA/cm^2) of small cross-section ($S < 1 \text{ mm}^2$). The undeniable advantage of this cumulation mechanism over a conventional one based on the self-focusing of a high-current beam by its own magnetic field is a very low energy spread ($< 0.1\%$) of particles in the region of the maximum current density due to the laminar flow of charged particles.

Generation of high-current and high-voltage pulses by explosively driven magnetic flux compression devices

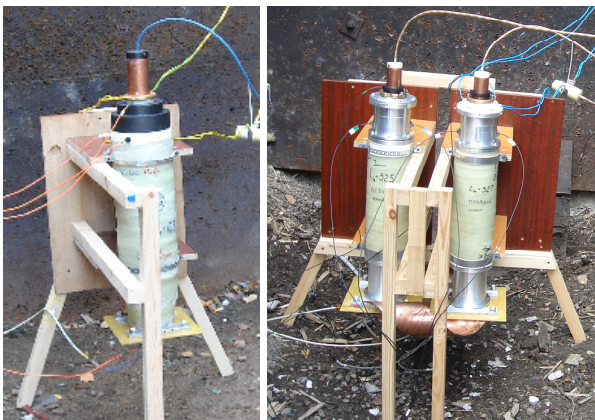
Research and development activities in field of magnetic energy cumulation accomplished with first flux compression generators (FCGs) tested in Belarus in 2004. From 2004 to 2015 more than 150 FCG prototypes were tested. Storing up to 100 kJ of electromagnetic energy they can produce current pulses with 3 MA amplitude.



FCG stator

Gained experimental and theoretical results deepen understanding of complex physical phenomena, which reveal at high energy density and accompanying motion of relativistic plasma and conversion of chemical energy of high explosives to electromagnetic energy.

Development of high power systems requested by different science and technology fields becomes possible.



FCG experimental prototypes

Development of FCG prototypes producing current pulses of 5MA amplitude is within the immediate laboratory plans. Application of explosively driven flux compression generators for seeding the high-current electron beam accelerators and radiation sources using electron beam energy for emitting radiation in different frequency ranges is also coming soon.

LABORATORY OF NUCLEAR OPTICS AND COSMOMICROPHYSICS



Head of the laboratory

Professor Victor Tikhomirov

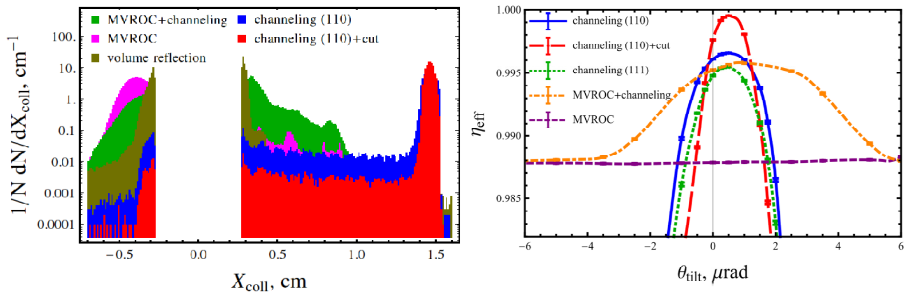
Tel: +(375 17) 226-47-39

e-mail: tikh@inp.bsu.by

Main research areas:

- effects of quantum electrodynamics and accompanying polarization phenomena under the penetration of high-energy particles through crystals, their application in acceleration physics;
- processes in dense substance and intensive fields in astrophysics and engineering;
- problems of the Universe creation and primordial black hole search.

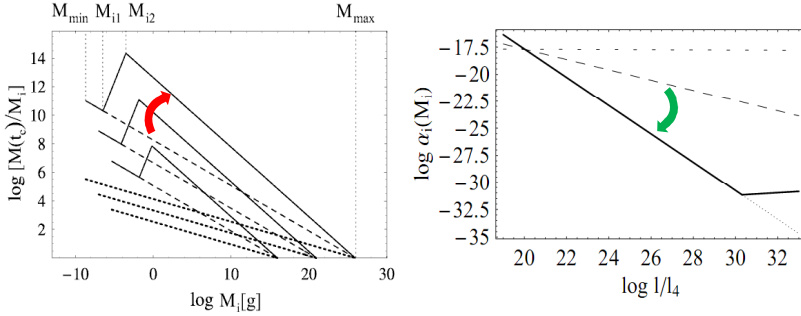
Laboratory researchers have predicted the effects of quantum synchrotron-like radiation by electrons and positrons and of synchrotron-like pair production by gamma-quanta in crystals, observed and studied at CERN, as well as a number of polarization effects accompanying the above. The anomalous energy losses by electrons in thin Germanium crystal were explained for the first time on the basis of radiation cooling effect.



Distributions of the transverse horizontal coordinate of particle incidence on the absorber (left) and the dependence of collimation efficiency on crystal alignment (right) under the channelling, multiple volume reflection in a one bent crystal and the crystal cut.

The problem of high energy particle beams collimation is actively investigated. The considerable excess of inelastic particle energy losses in the crystal collimator has been explained for the first time involving the misorientation of the crystal planes with its surface. New collimation methods, based on dedicated cut in crystal and multiple volume reflection effect, which was observed and studied at CERN recently, have been proposed. Several new LHC collimation schemes have been modeled and it was demonstrated that the crystal cut application allows increasing the collimation efficiency up to 99.95% and channeling efficiency up to 98%.

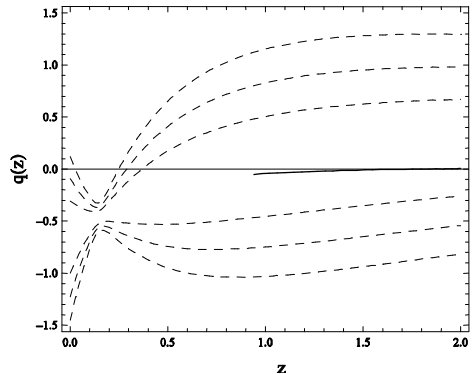
The methods of effective simulations of high-energy particle motion in crystals have been developed which allowed numerical interpreting of the number of experiments conducted both at CERN and MAMI microtron. The most reliable evaluation of both electron and positron radiation spectra in crystal undulators have been accomplished.



Mass M growth of 5D PBH for different curvature radii l (left) and corresponding constraints on PBH mass fraction α due to dark matter distribution (right). Dotted and dashed lines represent previous studies.

The theoretical models of absorption of white dwarfs, planets, neutron and normal stars by primordial black holes (PBH) have been developed which made it possible to set up new restrictions on their abundance. It was shown that the rate of accretion onto PBH increases significantly in the five-dimensional Randall-Sundrum Type II brane-world cosmology due to the collisions of particles of cosmological plasmas. This, in turn, leads to a much tighter constraints on initial PBH mass fraction imposed by different physical process, starting from primordial nuclear synthesis.

A theory with second order ties has been suggested instead of the general relativity to solve the problem of vacuum energy. The main part of the latter density does not influence the Universe expansion, while the latter is induced by its residual part only in the suggested theory. The earliest expansion stage in it is similar to the Milne Universe in which the scale factor increases linearly with time.



Universe deceleration parameter q dependence on the red shift z at different matter energy densities. Dashed lines limit the admissible q regions following from the supernova SN Ia data.

LABORATORY OF NANOELECTROMAGNETICS



Head of the laboratory

Dr. Polina P. Kuzhir

Tel: +(375 17) 200-74-10

e-mail:
polina.kuzhir@gmail.com



Scientific Leader

Professor Sergey Maksimenko

Tel: +(375 17) 200-84-81

e-mail:
sergey.maksimenko@gmail.com

Main research areas:

Research activity of the laboratory lies at the intersection of physical and quantum electronics, condensed matter physics and electromagnetism and resulted in the crystallisation and fast development of a new research discipline – ***nanoelectromagnetics***, which integrates approaches and methods of classical electrodynamics and present-day quantum physics of condensed matter aiming with modelling of electronic and electromagnetic properties of nanostructures. Research has been started in 1996 and covers the following key areas:

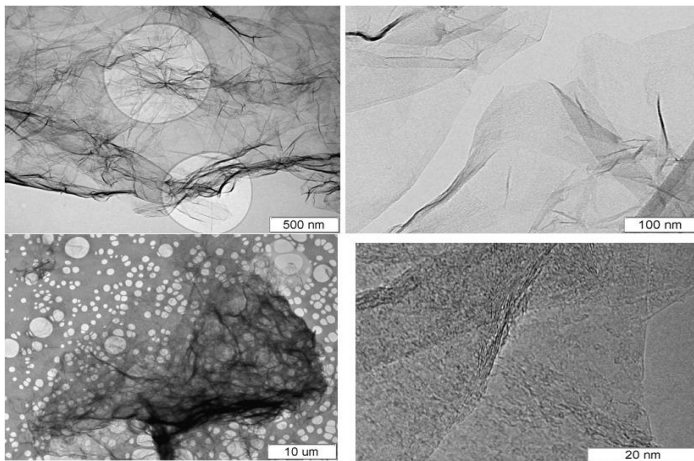
- linear and nonlinear electrodynamics of nanostructures;
- quantum optics of nanostructures;
- nanostructured composite materials;
- active nanostructures.

The research carried out during expired twenty years forms ***nanoelectromagnetics*** as well-recognised research direction providing pioneering results in prediction of physical effects in nanostructures and their electromagnetic response properties. The approach being developed to the description of physical processes in nanostructures allowed prediction and explanation of quite a number of new physical effects in carbon nanostructures and semiconductor quantum dots, and in macroscopic ensembles of such objects, and propose concepts of nanodevices utilizing these effects. Started as a fundamental research, presently the work encompasses a wide spectrum of applied problems, including the design of wideband electromagnetic shielding coatings for giga- and terahertz ranges on the base of different forms of nanocarbon (carbon nanotubes, onon-like carbon, graphene platelets, pyrolytic carbon, etc.). Basic concepts of electrodynamics of carbon nanotubes have been



Laboratory of Nanoelectromagnetics

developed [G.Y. Slepyan et al., Phys. Rev. B 17136, 1999], and the effect of strong slowing down of surface wave in carbon nanotubes, as much as 50-100 times, has been predicted. The study of antenna properties of isolated finite-length carbon nanotubes allowed qualitative interpretation experimentally observed peculiarities of the electromagnetic response of CNT-based composite materials in terahertz and far-infrared frequency ranges and give for the first time experimental evidence of antenna nature of the terahertz peak in the conductivity of CNT thin films and CNT-based composites [M.V. Shuba et al., Phys. Rev. B 165435, 2012]. Realizability of the Cherenkov mechanism of amplification and generation of electromagnetic waves in the THz range by nanotubes' π -electrons has been theoretically demonstrated and a concept of CNT as a monomolecular travelling wave tube has been proposed [K.G. Batrakov et al., Phys. Rev. B 125408, 2009].



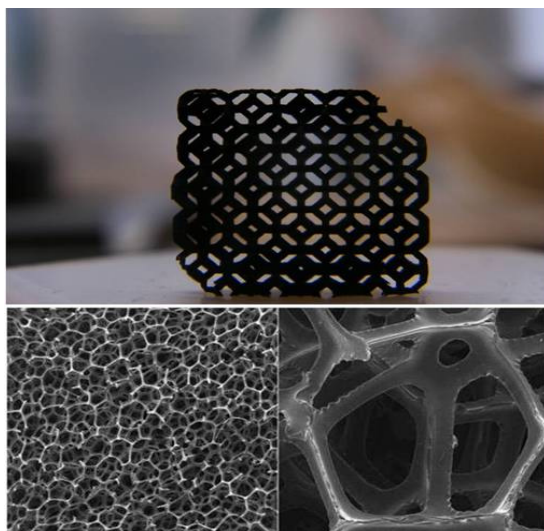
Pyrolytic carbon thin films

Experimental study of microwave radiation interaction with ultra-thin carbon films and graphene/PMMA sandwiches were started in 2013. The results obtained demonstrate high potential nanoscale films made of pyrolytic carbon and graphene mono- and multi-layer structures for microwave applications: it has been found that carbon or graphene layer of the thickness from several to several tens nanometers absorbs about 50% of the electromagnetic radiation in the giga- and terahertz frequency ranges (having been many orders of magnitude thinner than the skin depth.) [K. G. Batrakov Sci. Rep. 7191 2014].

Recently, new and very promising electromagnetic materials - porous carbon micro- and nanostructures (foams, meso- and aerogels, hollow spheres) - have attracted our attention [D. Bychanok Appl. Phys. Lett. 013701, 2016]. Diversity of porous carbons (random and ordered structures, 3D-periodic lattices, etc.) provides possibilities for the design of materials and metamaterials with unique thermal, electric and electromagnetic properties.

The Nanoelectromagnetics Laboratory is equipped with:

- Scalar analyser for the frequency range 26-37 GHz (Elmika, Lithuania)
- Terahertz spectrometer T-Spec (EKSPLA, Lithuania)
- CVD reactor for the multi-walled CNT synthesis (Institute of inorganic chemistry, SB RAS, Novosibirsk, Russia) IHX
- CVD reactor for the large-area (25-30 sq. cm) synthesis of graphene and other 2D carbon thin films (in the construction)



Carbon foams

Activity of the laboratory in the area of fundamental and applied nanoelectromagnetics is widely recognized due to high-level scientific results and wide international cooperation. We participated and participates presently in a number of projects supported by EU FP6, FP7 “Horizon-2020” as well as NATO SfP and ISTC. In particular, S.A. Maksimenko is a first Belarusian scientist coordinating EU FP7 project, “Institutional development of the applied nanoelectromagnetics: Belarus in ERA widening (FP7-266529 BY-NanoERA). For achievements in

nanoelectromagnetics S.A. Maksimenko has been elected as SPIE Fellow. The laboratory team is the only participant outside EU in the EU megagrant GRAPHENE FLAGSHIP “Graphene-Based Revolutions in ICT And Beyond, Multi-layered sandwich graphene device”, projects FP7- 604391 and Horizon 2020 696656 (Dr. P. Kuzhir is the executing leader). In addition, the EU projects FAEMCAR, CANTOR, NAMiceMC, EC COEXAN are currently carried out in the laboratory. Stable cooperative links have been established with Rysan State Radiotechnical University, Institute of Inorganic Chemistry SB RAN and Institute of Catalysis SB RAN, Tomsk State University, etc. A joint research and education laboratory on carbon nanomaterials has recently been established with the Harbin University of Science and Technology. Four co-workers, K. Batrakov, P. Kuzhir, S. Maksimenko and G. Slepyan have been awarded by the Acad. A. N. Sevchenko prize (2011).

The nanoelectromagnetics team organized a set of thematically closed events, such as International Conference “Fundamental and Applied NanoElectroMagnetics”(FANEM 2012), and NATO Advanced Research Workshop with the same title FANEM 2015.

LABORATORY FOR PHYSICS OF PROSPECTIVE MATERIALS

Main research areas:

• Design and fabrication of nanostructured magnetic materials:

- multilayered 3d-metal – Pt, Pd/CoO, IrMn thin films with patterned structure,
- granular metal-insulator films 3d-metal –Al₂O₃, PZT, CaF₂,
- core-shell” nanoparticles 3d-metal – Pt, Pd, Au, Ag,
- magnetic nanoparticles on graphene.

• Mechanisms of magnetization reversal and electrical conductivity in magnetic field

Particular attention is devoted to magnetoresistance, magnetization reversal and switching behavior (including domain wall propagation and coherent/incoherent rotation) in superparamagnetic and/or patterned nanostructures (nanowires, nanodots, antidots) with perpendicular magnetic anisotropy and FM-AFM exchange bias. The emphasis is placed on the structure-property relationships through comprehensive characterizations of materials.

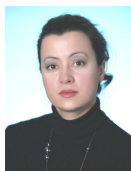
• Local atomic order studied by ⁵⁷Fe Mössbauer spectroscopy and X-ray absorption spectroscopy

Precise and highly sensitive identification of magnetic state, phase composition, oxidation and atomic ordering by analyzing local structure in nanoobjects.

Application areas: fabrication and testing of new magnetoelectronic (spintronic) devices, bio-sensors, magnetic tunnel junctions, magnetic sensors for high-frequency applications, magnetic sensors with high spatial resolution, media for high-density recording.

Characterization techniques include: vibrating sample magnetometry, ⁵⁷Fe Mössbauer spectroscopy, magnetic resonance spectroscopy, X-ray diffraction, scanning electron microscopy, transmission electron microscopy, X-ray absorption spectroscopy (XANES, EXAFS in collaboration with DESY).

Laboratory is the key organizer of bi-annual international meeting “Modern nuclear research methods in condensed matter physics” related to the application of neutron diffraction, neutron scattering and neutron activation analysis for study of nano- and biostructures, nanolayers, polymers and complex liquids.



Head of the laboratory

Dr.Sci. Julia Fedotova

tel: +(375 17) 233-90-48

e-mail: julia@hep.by



Mössbauer spectrometer with closed cycle refrigerator

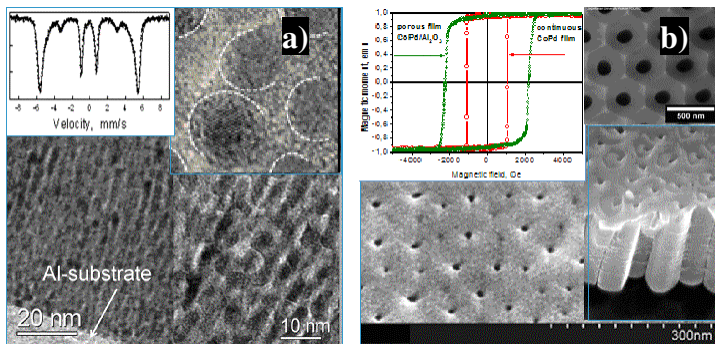


Illustration of nanostructures (granular films (a) and porous films (b)) with perpendicular magnetic anisotropy analyzed in the LPPM

Main results:

Physical concept for fabrication of multifunctional metal-insulator films with stabilized granular nanostructure due to selectively oxidized core-shell nanoparticles and possessing enhanced magnetoresistive effect, negative capacitance, tunable electrical conductivity and magnetization.

Physical principles for preparation of granular "metal-insulator" nanocomposite films with enhanced perpendicular magnetic shape anisotropy by partial nanoparticles oxidation and irradiation with heavy ions.

Fabrication of nanoporous CoPd, CoPt thin films on flat-surface Al_2O_3 and TiO_2 templates with perpendicular magnetic anisotropy and enhanced remanence.

Elaboration of technique for electrochemical deposition of separated magnetic nanoparticles on graphene with subsequent nanoparticles coating with noble metals by redox-transmetalation technique.

LABORATORY OF THEORETICAL PHYSICS AND SIMULATION OF NUCLEAR PROCESSES



Head of the laboratory

Dr. Siamion Kutsen

tel: +(375 17) 226-42-25

e-mail: kut@inp.bsu.by

Main research areas:

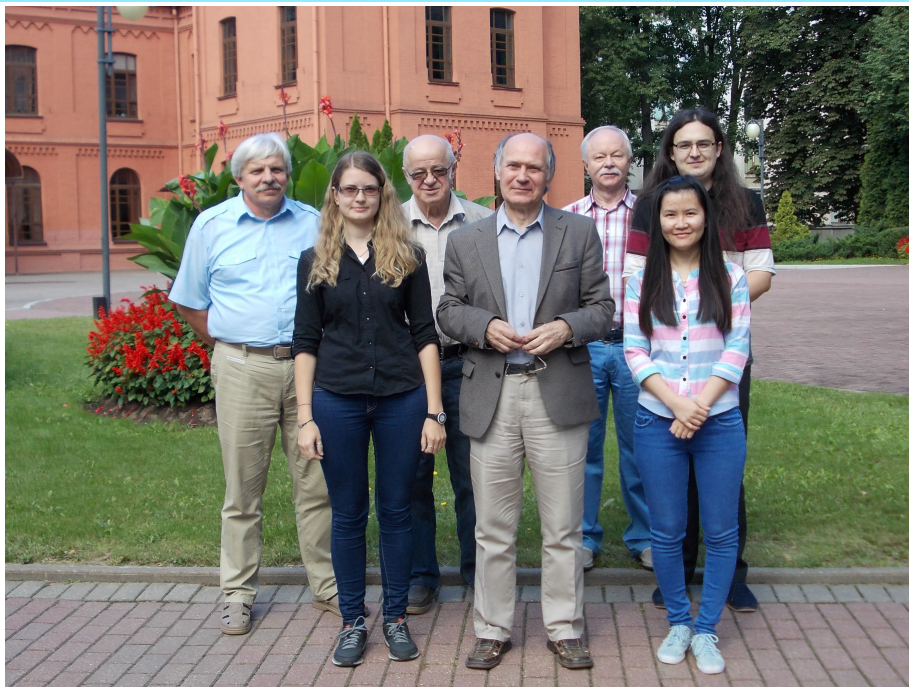
• Fundamental research

- High energy physics and study of spin effects occurring in particles in electromagnetic and gravitational fields.
- Foldy-Wouthuysen transformation in relativistic quantum mechanics.
- Computer simulations of carbon nanostructures and their derivatives. Study of carbon nanostructures (nanotubes, nanocrystals, fullerenes, carboranes and their derivatives), that are the main elements of biosensors and precursors of anticancer materials, physical-chemical methods and methods of molecular dynamics and quantum chemistry.
- Quantum chemical simulation of chemical properties of nanostructures (NV-centers in diamond as a base for quantum computer, quantum cryptography devices, magnetometers for biological objects, single photon sources).
- Study of spin relaxation in solid state matter.

• Applied research

- Medical physics:
 - Computer simulation of patient radiation doses during diagnostic radiology.
 - Radiation protection of radiotherapy patients.
 - Dose reconstruction from incorporated radionuclides in human thyroid and whole body after Chernobyl accident.
- Monte-Carlo simulation of instruments for nuclear physics: dosimeters, radiometers, scintillation spectrometers of ionizing radiation, whole-body counters (WBC) to measure spectrum of ionizing radiation in human body, neutron diffractometers for materials science, devices for measurement of neutron flux in a nuclear reactor core.
- Development of mathematical methods and use of computer programs to calculate steady state mode and transient regimes (including accident situations) of WWER-type nuclear reactors.

In the field of fundamental research general laws of Dirac fermion dynamics in curved space were determined, general quantum-mechanical Hamiltonians and equations of motion were derived, the contribution of space curvature was found, and by analyzing modern experimental data new experimental limits of Cartan curvature were determined.



Personnel of the laboratory

Jointly with scientists from NAS of Belarus the properties of nitrogen-vacancy (NV) center in diamond as a prototype of quantum processor are studied. A “stability island” in the position of ^{13}C isotope with respect to the NV center was found. Coherence time for the nuclear spin of ^{13}C at room temperature is tens of minutes.

Radiation dose formation in patients during diagnostic medical exposure was studied. Modern methods of Monte-Carlo simulation of radiation transport in voxel phantoms of human were used. Computer suite “Radiologist’s calculator” was developed for express estimation of radiation doses to organs and tissues and effective doses to patients of various ages in 1350 diagnostic procedures. For the first time in Belarus the work on radiation safety to study the contribution of secondary neutron radiation to patients and personnel radiation doses during radiotherapy on high energy electron linacs in the hospitals of Belarus was carried out.

In participation with National institute of cancer (USA) a series of studies were performed on retrospective estimation of radiation doses to thyroid of residents of the territories contaminated with radionuclides after the Chernobyl accident.

The laboratory actively takes part in the development of mathematical methods and use of computer programs to calculate steady state mode and transient regimes (including accident situations) of the reactor of Belarusian NPP.

LABORATORY OF NUCLEAR SPECTROMETRY AND EXPERT EVALUATION OF RADIATION SAFETY



Head of the laboratory

Professor Alexander Lobko

tel. +(375 17) 328-61-76;

e-mail: lobko@inp.bsu.by

Main areas of the laboratory activity:

- **Interaction of ionizing radiations with matter**

Laboratory associates perform basic and applied research in areas as follows:

- physics of interaction of ionizing radiations with matter;
- nuclear spectrometry;
- physics and engineering of detectors for ionizing radiations.

- **Expert evaluation of radiation safety**

Laboratory performs expert evaluation in the area of radiation safety under permit No33134/615-4 issued in May 2nd, 2016 by the Department for Nuclear and Radiation Safety of the Ministry for Emergency Situations.



Along with the above activity Laboratory developing proposal for the Department for Nuclear and Radiation Safety to perform instrumental verification of meeting up-to-date parameters of the x-ray equipment to the approved technical specifications during official on-site inspections of the Belarusian medical institutions. Laboratory holds non-invasive x-ray evaluator of radiation outputs Victoreen NERO mAx Model 8000 standardized by the Institute for metrology as well as dedicated test phantoms for quality inspection of the medical x-ray equipment.



Group of the radiation safety experts at INP BSU

LABORATORY OF ANALYTICAL RESEARCH



Scientific Leader

Dr. Siarhei Charapitsa
tel: +(375 17) 212-17-26
e-mail: chere@inp.bsu.by

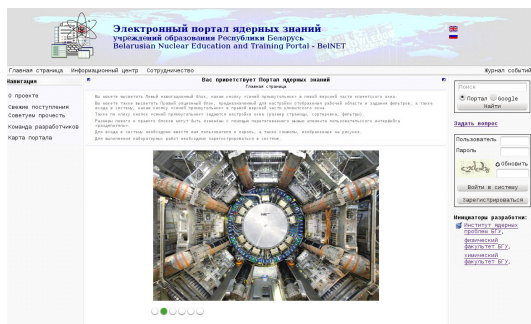


Head of the laboratory

Dr. Svetlana Sytova
tel: +(375 17) 226-47-39
e-mail: sytova@inp.bsu.by

Main research areas:

- methods of quality control of alcohol and alcohol-containing products;
- development of electronic document management system of the testing laboratory based on advanced algorithms and free software;
- development of content management system (CMS) of educational and research portal eLab-Science. On its basis the educational and research portal of nuclear knowledge BelNET (Belarusian Nuclear Education and Training) was developed;
- explore ways to develop the project on unification of working with various analytical instruments;
- study of mathematical models for the implementation of modern methods of detailed hydrocarbon analysis (Detailed Hydrocarbon Analysis – DHA) composition of the substance, including automobile gasoline and diesel fuels.



Belarusian Nuclear Education and Training Portal BelNET

An original content management system eLab-Science for educational and scientific portal is developed on the basis of the Belarusian software. Belarusian nuclear education and training portal of education institutions of the Republic of Belarus BelNET

was developed and now is available at: <https://bsu.inpnet.net/belnet/index.php?l=en>.

CMS eLab-Science is based on the framework eLab developed by scientists of the Laboratory. eLab has a client-server architecture based on free software: Debian GNU/Linux, Web-server Apache, the Firebird database server using PHP application server. The system runs under Windows and Linux operating systems. The work is carried out through the Internet in multiplayer mode, with the division of access rights by way of widespread browsers. eLab distinctive features are the next: division of databases on the system database and user database, maintaining the current the state of the user interface, work in real-time with opening data pages in less than half a second when using the internal (corporate) network. In 2012, the system eLab-Fuel (electronic document management system of the testing laboratory) put on combat

duty in 202 Chemmotology Center of the Fuel for quality monitoring and accounting of petroleum products of the Belarusian Armed Forces.

Authors obtained 4 certificates of the National Center of Intellectual Property of Belarus for registration computer program for different software products eLab.

New method of control of quality and safety of alcohol and alcohol-containing products

A new method of direct determination of the quantitative content of volatile compounds in alcoholic beverages using ethanol as internal standard was proposed. The method allows the correct determination of quantities of investigated concentration of volatile compounds in the test alcohol samples, when the volume content of volatile compounds exceeds 0.5%. It allows to simplify the testing procedure in general. On its basis of on-line AlcoDrinks calculator is developed <http://inp.bsu.by/calculator/vcalc.html>.

It was obtained the Certificate of certification procedure (method) No. 253.0169/01.00258/2013 by Federal Agency for Technical Regulation and Metrology of the Russian Federation (Rosstandart) "Method of measurement of the mass concentration of volatile compounds in alcohol drinks by gas chromatography".



Other results and achievements:

- The series of theoretical and experimental studies to determine the main parameters of the inspected vehicle fuels on the basis of DHA data were planned and executed. The State Standard of the Republic of Belarus STB 1276-2001 «Fuel for internal combustion engines. Gasoline unleaded. The method of calculating» was approved.
- It is planned and carried out a series of experimental studies in collaboration with the Laboratory of the chemical-toxicological studies of the Minsk City Drug-Dependency Clinic for metrological certification of techniques of gas chromatography determination of ethanol content in liquid biological environments of the body MVI 1329-2001. All studies on the definition of ethanol content in human biological fluids (blood, urine, saliva) in the Republic of Belarus are carried out by MVI 1329-2001.
- Within the framework of a Republican program of Standardizations the national standard Belarus STB 1287-2001 «Gas chromatographs analytical system of registration, processing and storage of spectrometric information Unichrom 97. Validation procedure» was developed and approved.
- It is developed a software package UC-NGA to unify performed calculations to determine the component composition of natural gas fuel and its main parameters inspected in accordance with international and national standards ISO 6974 (GOST 31371) and ISO 6976 (GOST 31369).

RADIOPHYSICS RESEARCH LABORATORY

Main research areas:

VHF-systems and components:

- equipment for researches in VHF-range;
- high-Q-factor resonance systems.

Interaction of electromagnetic waves and biological objects:

- presowing biophysical treatment of agricultural seeds;
- microwave sterilization and drying of foodstuff and materials.

Electrodynamics of heterogeneous mediums:

- new types of high quality resonance VHF systems;
- research of electrodynamic characteristics of nanomaterials.

The high quality resonance systems

The high quality VHF resonators are used to create the high quality signal sources of the radar and navigation systems, for carrying out the spectral and frequency measurements, for carrying out the physical researches. The VHF resonators are used: in the VHF electronics: the resonance and stabilizing systems of generators; in the measuring techniques: the wavemeters, the filters, the measuring instrument for signal spectrum, the frequency discriminators; in the experimental physics: the spectroscopy of electronic paramagnetic resonance, the measuring of materials parameters, etc.



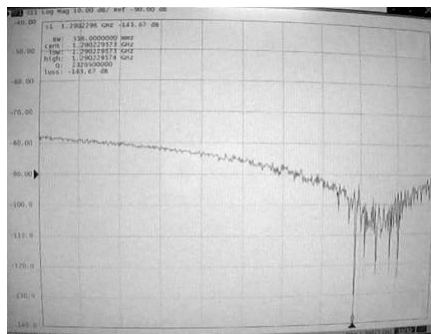
Head of the laboratory

Dr. Victor Karpovich

tel: +(375 17) 226-42-20

e-mail:

karpovich@inp.bsu.by



Q factor about $2.4 \cdot 10^9$ of the superconducting niobium resonator

Equipment for neutralization of the dangerous medical waste.



The new generation of the equipment for neutralization of the dangerous medical waste on base unified functional design of neutralization of the dangerous medical waste of the high-temperature microwave heating and sterilisations (from 900 °C to 1200 °C).

The application of the new technology: neutralization of the dangerous medical waste by ecological safe methods in accordance with

principle of the Basel convention in the field of ecological clean management public health.

The presowing biophysical treatment of the agricultural seeds

The presowing biophysical treatment of the agricultural seeds is the ecologically friendly biotechnology used for the growing vegetable crops (tomatoes, cucumbers, flax, rape, cotton, etc). The base of this technology is the informational influence of the low power level microwave energy on the biological objects. The application of this technology raises the physiological activity of the plants, annihilates the seed infection, and contributes to the better growing and development of the plants and the more early yielding.

Microwave presowing treatment of seeds

- to inhibit the seed infection
- to increase the germinability of seeds
- to improves the root system development
- to increase the photosynthesis-
ing apparatus of plants
- to promote the faster develop-
ment of plants



The microwave sterilization, heating and drying of the foodstuffs and materials

The high effective energy-saving technology of the foodstuff and material sterilization for the different branches of industry and agriculture is based on the high absorption of



the microwave energy by the dielectric materials. The construction and productivity of the equipment are developed according to the customers requirements. The technology of the microwave sterilization is characterized by the high effectiveness of the microwave energy transformation into the thermal energy and the non-contact heat of the treated material.

LABORATORY OF EXPERIMENTAL HIGH ENERGY PHYSICS



Head of the laboratory

Dr.Sci. Mikhail Korjik

tel: +(375 17) 200-39-82

e-mail:

korzhik@inp.bsu.by

Main research areas:

• Fundamental research:

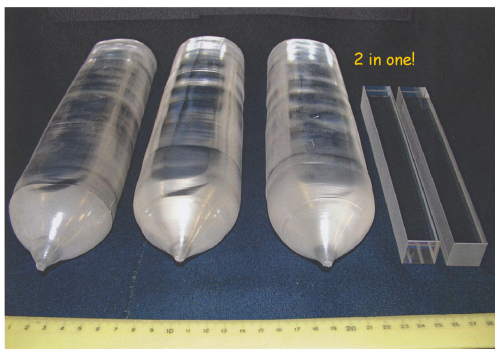
- development of a new generation of scintillation materials and detectors for experimental research in high energy particle physics,
- development of new methods for detecting of ionizing radiation including the subpicosecond timing domain.

• Applied research:

- development of principles of future detection systems suitable for hard radiation exposure conditions at HL LHC and FCC.

Since the beginning of the nineties the systematic studies of the properties of the crystal compounds were initiated in INP BSU under the supervision of M.V. Korjik. The work was aimed to create a new generation of high-efficiency transformers of ionizing radiation energy into light, e.g. scintillators. Such materials were required to develop and create a new generation of diagnostic equipment in nuclear medicine, detection techniques of fissile materials and for the experiments at LHC. These areas require to use of scintillation materials combining high density, high output and outstanding radiation hardness.

A new class of scintillation materials – PWO was developed in the laboratory in cooperation with CERN. On the basis of the heavy lead tungstate

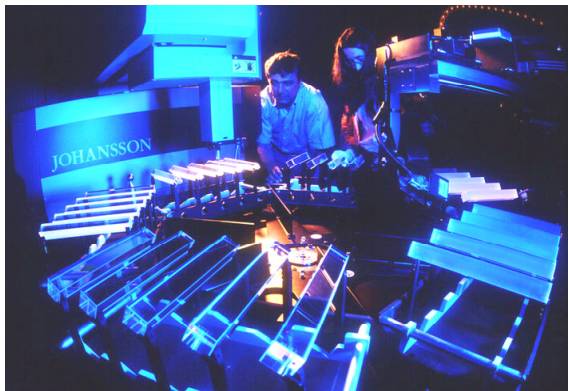


Lead tungstate crystals for electromagnetic calorimetry at LHC experiments

scintillator the electromagnetic calorimeters for CMS and ALICE detectors were built. The 90 thousands of the crystals were grown for 8 years in the framework of international collaboration at Russian plants. The laboratory carried out the scientific supervision for the production. The automated crystal quality control system was developed, which became a standard for manufacturers of inorganic scintillation crystals worldwide. The development and implementation of PWO scintillators for experimental high energy physics is one of the most noticeable implementations into international projects made by CIS scientists over the past twenty years. The laboratory has carried out 6 ISTC projects and is currently working on projects under Horizon 2020 program.

The new challenges for the laboratory are the participation in CMS detector upgrade program in order to operate with increased luminosity, the preparation of technical proposals for FCC detectors, participation in communication and infrastructure projects at CERN.

Automated crystal quality control system



Young scientists in the laboratory

INP facility for precise optics production



CENTER FOR PARTICLE AND HIGH ENERGY PHYSICS

In 2015 the Center for Particle and High Energy Physics (CPHEP) was merged with the Institute. The center consists of the three laboratories: Laboratory of Fundamental Interactions, Laboratory for Particle Physics and the Laboratory of Electronic Methods and Tools of Experiments.

Since 1992 (since 1995 as a part of RDMS CMS collaboration) under the leadership of the founder of the center N.M. Shumeiko our scientists and engineers were actively involved in preparation of the CMS experiment at LHC. The huge work has been carried out on technical support for engineering and production (together with JSC "MZOR") of the elements of the end-cap hadron calorimeter for the CMS experiment. The scientists of CPHEP are actively involved in detector maintenance, physics program development, data analysis and detector upgrade plans.

Since 2003 CPHEP takes an active part in the preparation of ATLAS experiment at LHC. The work is done both on the scientific and technical support of detector element production at belarusian enterprises (RUE "Minsk Tractor Works") and on the development of the physics program and data analysis.

Since 1998 CPHEP cooperates closely with DESY (Germany). Our scientists took active part in the experiments ZEUS and FLASH, projects TESLA and ILC. In 2013 CPHEP has joined the newly formed international collaboration CLICdp devoted to the preparation of the detector model and physics program at the future linear collider CLIC.



Staff of the center for particle and high energy physics

LABORATORY OF FUNDAMENTAL INTERACTIONS

Main research areas:

- calculation of radiative effects for processes of particle interaction;
- development and maintenance of Monte-Carlo generators for simulation of particle interaction processes;
- data analysis in modern accelerator experiments (LHC, CEBAF);
- quantum field theory and gravitation at low and high (Planck scale) energies, physics of Early Universe, cosmology and problems of dark energy and dark matter.

The scientists of laboratory have developed a number of generator codes that allows to simulate with high accuracy the behavior of processes of elastic and inelastic particle scattering in the number of modern and future accelerator experiments. The new knowledge on the nucleon structure and fundamental interactions have been obtained in the experiment data analysis.

The Hallmark of the laboratory is the number of works on the precision analytical calculation and numerical analysis of the higher-order perturbation theory effects in the kinematic conditions of the experiments.

In the framework of the CMS experiment the work is ongoing on the analysis of the differential cross section of the Drell-Yan process, backward-forward asymmetry and search for new heavy gauge bosons. In the framework of the ATLAS experiment we are focused on the analysis of multiple hadron jet events and heavy gauge boson production in order to obtain new knowledge about the partonic structure of the proton.

The actively developing research directions are the contemporary problems of cosmology and physics of the Early Universe. Dr.Sci. A.E. Shalyt-Margolin has developed a new approach to the quantum theory of the Early Universe, which may make it possible to solve many fundamental problems of modern theoretical physics: the problem of divergences in quantum field theory, the problem of transition from low to high energy in gravity, the dark energy problem.

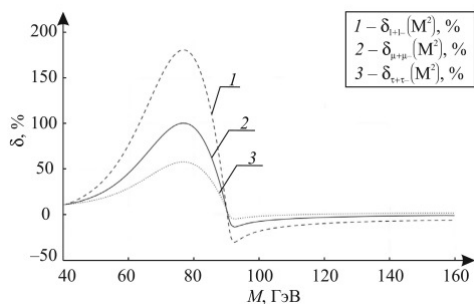


Head of the laboratory

Dr. Juan Suarez

tel: +(375 17) 294-80-12

e-mail: suarez@hep.by



The dependence of the electroweak radiative correction contribution to the process of electron (1), muon (2) and tau lepton (3) production in the CMS experiment on the invariant mass of lepton pair at center of mass energy 13 TeV [Phys. Part. Nucl. Lett. 13 (2016) 279]

LABORATORY OF PARTICLE PHYSICS



Head of the laboratory

Dr. Igor Emeliantchik

tel: +(375 17) 294-13-68

e-mail: igor@hep.by



Scientific Leader

Dr. Michail Batouritski

Tel: +(375 17) 233-90-41

e-mail: m_batouritski@hep.by

Main research areas:

- Design of custom integrated circuits for front-end electronics of detectors for particle physics;
- Development of superconducting niobium resonators for particle accelerators;
- Research and development of diamond detectors of charged particles for colliders of next generation.

Front-end electronics, created under direction of M.Batouritski, on the base of custom integrated circuits of 8-channel transimpedance amplifiers Ampl-8.3 and comparators Disc-8.3, has allowed to produce and successfully use muon systems of such well known projects as D0 (Fermilab, USA – 1997-2013), COMPASS (CERN, 2003 up to now), tracker of SVD-2 detector (IHEP, Russia). Ampl-8.3 is used in PiBeta experiment (PSI, Switzerland).

Amplifier-discriminator chip AD-1.3 and small size module ADB-1.3 are developed. They can be builded into drift and mini-drift tubes. It increases its reliability.

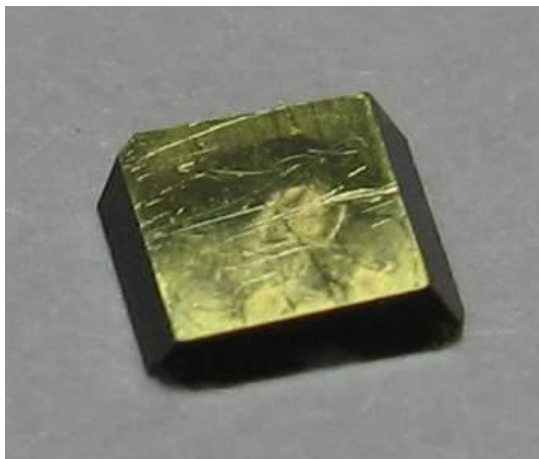
Custom chips for registration of detector signals were developed under direction of M. Batouritski. Chips were designated for particle physics research (experiments “Multiparticle spectrometer” and “Universal calorimetric detector” in the frame of “High energy physics”

program of the State committee for science and technology of USSR), projects GEM (supercollider SSC, USA) and CMS. Development of amplifier chips with low-resistivity input (3 – 12 Ohm) is going on. These chips are designed for mini-drift tubes with open cathod geometry for muon system and electromagnetic calorimeter of PANDA detector (GSI, Germany) and NICA-MPD experiment (JINR, Russia). Development of custom and semi-custom chips of single-channel amplifiers-discriminators and multi-channel amplifiers and comparators for registration of signals of SiPMs is going on. These chips are intended to use in hodoscopic and calorimetric systems of experiments PANDA and NICA-BM@N.



32-channel plates installed in mini-drift tubes of the D0 forward muon system

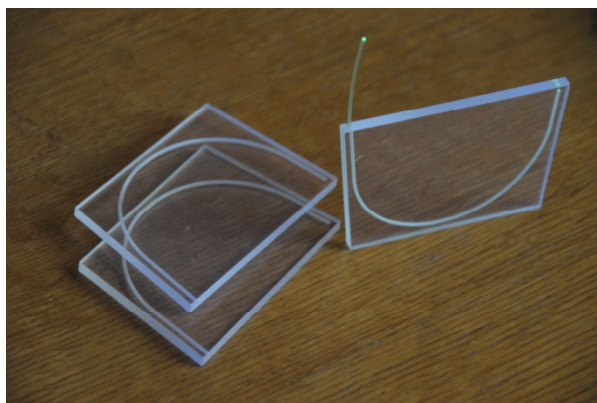
Members of laboratory have performed a set of research and development works on diamond detectors of charged particles for colliders of next generation. Efficient methods of selection of synthetic diamond crystals suitable for production of particle detectors are created. Methods are based on analysis of photoluminescence and photo-consumption spectra. Influence of catalytic environment of diamond synthesis and the mode of consequent diamond thermo baric processing on the main quality parameters of diamond detector is researched. Development and comparative research of detectors on the base of monocrystalline and CVD diamonds for International Linear Collider is performed.



Metallized plate of synthetic single-crystal diamond for detecting of charged particles

Prototype of detector of ionizing radiation with increased efficiency on the base of synthetic diamond monocrystals is developed.

Members of laboratory actively took part in development and production of end cap hadron calorimeter of CMS experiment.



Active elements of the end-cap hadron calorimeter in the CMS experiment

Members of laboratory in collaboration with JINR colleagues have performed investigation of early degradation of CMS plastic scintillator, which prevented its use in High Luminosity mode. The cause of this degradation was found, and recommendations on its overcoming were formulated.

Preparation of research and development program

of design and production of superconducting resonators for linear proton accelerator (up to 50 MeV) has started. This accelerator should replace the proton injector LU-20 (JINR, Russia).

LABORATORY OF ELECTRONIC METHODS AND TOOLS OF EXPERIMENTS

Main research areas:

- methods and techniques of experiment,
- calculation and simulation of physical electronics and devices,
- Development, manufacture support and testing of application-specific analog and mixed-signal integrated circuits (IC) for nuclear electronics, radio-electronic and electronic measuring equipment,
- Development of electronic components and assemblies for the experimental equipment used in modern particle physics experiments,
- Improving the measurement techniques and simulation of parameters of electronic components,
- Development and prototyping of specimens of specialized control and measurement electronics for testing IC and modern element base.

Laboratory staff is actively involved in research and development work on creating microelectronics for signals registration in CMS muon detector at LHC, on build and commissioning of the end-cap of the CMS muon detector.

Laboratory staff participated in testing, installation and putting into exploitation of the ME1/1 cathode strip chambers (CSC), the elements of CMS muon detector. In collaboration with colleagues from JINR and CERN the CSC of the end-cap muon detector has have been commissioned, the end-cap part of the detector systems has been tested and adjusted to detect defects and to optimize the operation modes. In the framework of CMS upgrade program the electronic system for CSC on-chamber electronics for muon detector was designed and manufactured.

Laboratory staff are co-authors of engineering documentation on the CMS muon detector, an important part of the installation. The works was awarded the CMS collaboration prize «Achievement Award for CMS Construction»
(V. Tchekhovski, 2010).

An important activity of the laboratory is programmable analog microelectronic devices for hard, radiation-strained, operating conditions.

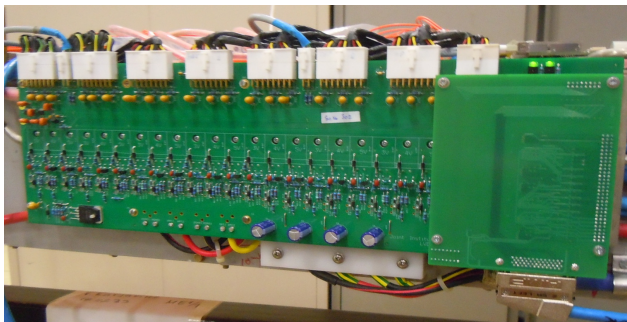


Head of the laboratory

Vladimir Tchekhovski

tel: +(375 17) 294-71-19

e-mail: vtchek@hep.by



*Electronic module for low voltage power supply system
of CMS muon detector*

SELECTED MONOGRAPHS AND PROCEEDINGS OF INP BSU ASSOCIATES

