XXII INTERNATIONAL CONFERENCE
"FOUNDATIONS & ADVANCES IN NONLINEAR SCIENCE"
AND
VII INTERNATIONAL SYMPOSIUM
"ADVANCES IN NONLINEAR PHOTONICS"

Programme & Book of Abstracts

Minsk, September 23–27, 2024

MINISTRY OF EDUCATION OF THE REPUBLIC OF BELARUS
BELARUSIAN STATE UNIVERSITY

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MINSK
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The book includes Programme & Book of Abstracts of the 22th International Conference “Foundations & Advances in Nonlinear Science” and 7th International Symposium “Advances in Nonlinear Photonics” (Minsk, September 23–27, 2024). The papers cover topics on fundamental aspects and modern state of art in such fields as self-organization theory, lasers and nonlinear photonics, astrophysics, quantum mechanics particle physics, nanoscience, biophysics and statistical mechanics.

Edited by *A. L. Tolstik* and *G.G. Krylov*

22th International Conference
Foundations & Advances in Nonlinear Science
23.09–27.09.2024
and
7th International Symposium
Advances in Nonlinear Photonics
23.09–27.09.2024

Minsk, Belarus

FANS & ANPh Conferences Programme & Abstracts

Monday 23.09.2024

FANS & ANPh REGISTRATION **9.00 – 10.00**
Physics Department, room 326

OPENING **10.00 – 10.05**
Physics Department, room 330
Foreword **by Chairman Prof. Alexei Tolstik**

Theoretical physics **10.05 – 11.55**
Physics Department, room 330 (Chairman G.G. Krylov)

10.05 – 10.35
Acceleration and twisting of neutral atoms by strong elliptically polarized short-wavelength laser pulses
Vladimir S. Melezhik, Sara Shadmehri (Joint Institute for Nuclear Research, Bogoliubov Laboratory of Theoretical Physics, Dubna, Russia)

10.35 – 11.05
Photon condensation in non-classical states in the Gauge invariant Dicke Model
N.Q. San[1], O.D. Skoromnik, A.P. Ulyanenkov[2], A.U. Leonau[3], I.D. Feranchuk[2]
([1]School of Engineering and Technology - Hue University, Vietnam, [2]Atomicus GmbH Amalienbadstr. 41C, 76227 Karlsruhe, Germany, [3]Deutsches Elektronen-Synchrotron DESY, Hamburg 22607, Germany)

11.05 – 11.35
Simulations and applications of the high-energy electromagnetic showers in oriented crystals
V.V. Tikhomirov, V.V. Haurylavets, A.S. Lobko, M.S. Sachyuka (Institute for Nuclear Problems of Belarusian State University, Minsk, Belarus)

11.35 – 11.55
Electric field of a charged ring located in the equatorial plane of Kerr black hole
S.O. Komarov, A.K. Gorbatsievich, G.V. Vereshchagin, A.S. Garkun (Belarusian State University, Minsk, Belarus)

Coffee Break 11.55 – 12.10
Physics Department, room 326

Theoretical physics 12.10 – 13.20
Physics Department, room 330 (Chairman V.V. Tikhomirov)

12.10 – 12.40
Studying the properties of ratchet systems by the Green's function method
V.M. Rosenbaum (Belarusian State University, Minsk, Belarus)

12.40 – 13.00
Bound states in the continuum in non-Hermitian layered structures
Denis Novitsky (B.I. Stepanov Institute of Physics, NAS of Belarus, Minsk, Belarus)

13.00 – 13.20
Gluon dominance model and multiplicity distributions of hadrons
Elena Kokoulina (Joint Institute for Nuclear Research, Dubna, Russia)

Lunch Break 13.20 – 15.00

Nonlinear dynamics, modeling and data analysis 15.00 –16.45
Physics Department, room 330 (Chairman A.V. Savin)

15.00 – 15.20
Modern tools for mathematical modelling of electronic amplifiers and generators of coherent radiation
Svetlana Sytova (Institute of Nuclear Problems of the Belarusian State University, Minsk, Belarus)

15.20 – 15.40
Chaotic mappings for images encrypting.
A.V. Sidorenko, I.V. Sergeev (Belarusian State University, Minsk, Belarus)

15.40 – 16.00
Object recognition on heterogeneous backgrounds using hybrid deep learning for spatial inverse problems
I.V. Saetchnikov, V.V. Skakun, E.A. Tcherniavskaia (Belarusian State University, Minsk, Belarus)

16.00 – 16.15
Mental Fatigue Induced by Exposure to a WiFi Range Electromagnetic Noise Generator
A.V.Sidorenko, M.A. Saladukha (Belarusian State University, Minsk, Belarus)

16.15 – 16.30
Topological properties of the optical Tamm states in a one-dimensional chain of microresonators
D.P. Fedchenko, A.S. Zuev, I.V. Timofeev (Kirensky Institute of Physics. Federal Research Center KSC Siberian Branch Russian Academy of Sciences)

16.30 – 16.45
Machine Learning-Driven Analysis of Carbon Nanotube Accumulation in Cancer Cells via Raman Spectroscopy
Igor Timoshchenko, Lena Golubewa, Tatsiana Kulahava (Belarusian State University, Minsk, Belarus)

Coffee Break 16.45 – 17.00

Nonlinear dynamics, modeling and data analysis 17.00 – 19.00

Physics Department, room 330 (Chairman Svetlana Sytova*)*

17.00 – 17.30
Self-organization of charged particles in lateral potentials with a high symmetry
Rashid Nazmitdinov (JINR, Dubna, Russia)

17.30 – 17.50
Complex dynamics in Hamiltonian-driven dissipative system
D.O. Lubchenko, A.V. Savin (Saratov State University, Saratov, Russia)

17.50 – 18.10
On an approximate formula for functionals with respect to stochastic Poisson measure
Anatoly Zherelo (Belarusian State University, Minsk, Belarus)

18.10 – 18.30
Optimizing 3D Ionosphere Reconstruction Algorithm Based on Modified Landweber Method for Enhanced Radiotomography Accuracy
A.O. Naumov (Institute of Applied Physics, Minsk, Belarus)

18.30 – 18.50
Geometric Models of Nonwandering Indecomposable Continua
Anna M. Khakhina[1], Dmitry Serow[2] (Peter the Great St., Petersburg Polytechnic University, Saint-Petersburg Russia, National Centre for Dynamic System Research RAS, Gatchina, Russia)

Tuesday 24.09.2024

Nonlinear photonics and laser dynamics 9.30 – 11.30

Physics Department, room 330 (Chairman E.A. Melnikova)

9.30 – 10.00
Dynamic holography for light fields transformation and materials diagnostics of advanced photonics and electronics
A.L. Tolstik (Belarusian State University, Minsk, Belarus)

10.00 – 10.20
A detailed study of the Bragg diffraction on the regular domain structures with inclined walls in 5%MgO:$LiNbO_3$ crystals
S.M. Shandarov, E.N. Savchenkov, A.V. Dubikov, D.E. Belskaya, S.V. Smirnov, N.I. Burimov (Tomsk State University of Control Systems and Radioelectronics, Tomsk, Russia), M.A. Chuvakova, A.R. Akhmatkhanov, V.Ya. Shur (Ural Federal University, Ekaterinburg, Russia)

10.20 – 10.40
Plasmon-Enhanced Optical Nanolithography
S. Kurilkina, N. Khilo (Institute of Physics of the NAS of Belarus, Minsk, Belarus)

10.40 – 11.00
Transverse structure of interfering laser beams in canonically conjugate coordinates
V.V. Kabanov, A.O. Nehryienka (Institute of Physics of the NAS of Belarus, Minsk, Belarus)

Coffee Break 11.00 – 11.15

Nonlinear photonics and laser dynamics 11.15 – 13.15

Physics Department, room 330 (Chairman A.L. Tolstik)

11.15 – 11.35
Nonlinear Resonances in Optoelectronic Artificial Spiking Neuron Based on a VCSEL and SPAD Driven by Periodic Signals and Noise
V.N. Chizhevsky, M.V. Lakhmitski, S.Ya. Kilin (B.I. Stepanov Institute of Physics, Minsk, Belarus)

11.35 – 11.55
Polarization Instabilities in Vertical-Cavity Surface-Emitting Lasers
L.I.Burov, P.M.Lobatsevich (Belarusian State University, Minsk, Belarus)

11.55 – 12.15
Nonlinear properties of biosuspensions
Kseniya Pestsova, Olga Fedotova, Oleg Khasanov, Ryhor Rusetski, Tatsiana Smitnova, Alexander Bugay (Scientific and Practical Center of the National Academy of Sciences of Belarus for Materials Science, Minsk, Belarus)

12.15 – 12.35
Modeling of coherently mode-locked lasers
Anton Pakhomov, Mikhail Arkhipov, Nikolay Rosanov and Rostislav Arkhipov (St-Petersburg, Russia)

12.35 – 12.55
Jones 4-Spinor and Partially Polarized Light
V.M. Red'kov, A.V. Ivashkevich, E.M. Ovsiyuk, V. Balan, A.V. Chichurin (B.I. Stepanov Institute of Physics, Minsk, Belarus)

12.55 – 13.15
Tunneling times for electromagnetic pulses propagating through a plasma layer
D. Novitsky, M. Usachonak, I. Timoshchenko, O. Romanov, L. Simonchik, S. Gaponenko
(B.I. Stepanov Institute of Physics, Belarusian State University, Minsk, Belarus)

Lunch Break 13.15 – 14.45

Materials and technologies 14.45 – 17.00

Physics Department, room 330 (Chairman H.V. Grushevskaya)

14.45 – 15.15
Vector magnetometry implemented using 14NV-13C hybrid spin systems in nanodiamonds
A.P. Nizovtsev, A.L. Pushkarchuk, A.T. Salkazanov, N.I. Kargin, S.Ya. Kilin (Institute of Physics, National Acad. Sci. of Belarus, Minsk, Belarus)

15.15 – 15.45
Superferromagnetoresistors
Vladimir Kondratyev (Joint Institute for Nuclear Research, Dubna, Russia)

15.45 – 16.15
On scattering resonances in monolayer and bilayer graphene circular quantum dots
G.G. Krylov (Belarusian State University, Minsk, Belarus)

16.15 – 16.35
Collapse of Klein tunneling resonances in pseudo-Majorana-type pn-graphene junctions
H.V. Grushevskaya and G.G. Krylov (Belarusian State University, Minsk, Belarus)

16.35 – 16.55
Hybridization of acoustic tamm states with defective modes of a one-dimensional phononic crystal
A.S. Zuev, S.Y. Vetrov, D. P. Fedchenko, I.V. Timofeev (Kirensky Institute of Physics. Federal Research Center KSC Siberian Branch Russian Academy of Sciences, Krasnoyarsk, Russia)

The cultural program 18.00

Wednesday 25.09.2024

Excursion 9.00 – 14.00

Online Session 14.00 – 16.15

Physics Department, room 330, http://eduphys.bsu.by
(Chairman G. Krylov)

14.00 – 14.20
Pulse compression and time delay of stimulated Raman scattering components in $Ba(NO_3)_2$ powder
A.D. Kudryavtseva, T.V. Mironova, M.A. Shevchenko, N.V. Tcherniega, S.F. Umanskaya
(P.N. Lebedev Physical Institute of the Russian Academy of Sciences, Moscow, Russia)

14.20 – 14.40
Scalar particle with the Cox structure and polarizability, in presence of the uniform magnetic field
E.M. Ovsiyuk, P.O. Sachenok, A.S. Martynenko, A.V. Ivashkevich (Mozyr, Belarus)

14.40 – 15.00
Temperature reversal of the ratchet motion direction due to tunnel effect
I.V. Shapochkina and V.M. Rozenbaum (BSU, Minsk, Belarus & DPU, Dalian, China)

15.00 – 15.20
Spin 1 Particle with Anomalous Magnetic Moment and Polarizability in presence of the uniform magnetic field
E.M. Ovsiyuk, P.O. Sachenok, A.V. Ivashkevich, A.V. Bury (Mozyr State University, Belarus)

15.20 – 15.40
Hardronic Decays of Heavy Lepton
S. Avakyan, E. Avakyan (Sukhoi State Technical University of Gomel, Gomel, Belarus)

15.40 – 16.00
Leptonic and Semileptonic Interactions of Charmed Mesons
E. Avakyan, S. Avakyan (Sukhoi State Technical University of Gomel, Gomel, Belarus)

16.00 – 16.15
Is it possible matching higher-twist contributions with chiral perturbation theory?
D.A. Volkova, N.A Gramotkov, O.V. Teryaev and O.P. Solovtsova (Dubna)

Coffee Break 16.15– 16.30

Theoretical physics 16.30 – 18.20

Physics Department, room 330 (*Chairman V.Red'kov*)

16.30 – 17.00
Ghost and Gluon Propagators at Finite Temperatures within a Rainbow Truncation of Dyson-Schwinger Equations
L.P. Kaptari, O.P. Solovtsova (Joint Institute for Nuclear Research, Dubna, Russia)

17.00 – 17.20
Matter transport as fundamental property of solitons. Generalization of the Stokes drift mechanism to strongly nonlinear systems.
F.M. Trukhachev, N.V. Gerasimenko, M.M. Vasiliev, O.F. Petrov (Belarusian-Russian University, Joint Institute for High Temperatures of the Russian Academy of Sciences, Mogilev, Belarus)

17.20 – 17.40
Half-cycle dissipative solitons in resonant media
Anton Pakhomov (St-Petersburg State University, St-Petersburg, Russia)

17.40 – 18.00
Kosambi-Cartan-Chern geometric invariants, and the structure of the radial differential equations for a Dirac particle in the Newman-Unti-Tamburino space-time
N.G. Krylova (B.I. Stepanov Institute of Physics, Minsk, Belarus)

18.00 – 18.20
Resonant tunneling in QCD
Roman Shulyakovsky (Institute of Applied Physics NAS of Belarus, Minsk, Belarus)

Thursday 26.09.2024

Nonlinear spectroscopy and laser-matter interaction 9.30 – 11.00

Physics Department, room 330 (*Chairman O.G.Romanov*)

9.30 – 9.50

Testing single micro-particles as individual luminescent upconversion probes

Victor G. Nikiforov, Andrey V. Leontyev, Larisa A. Nurtdinova, Evgeny O. Mityushkin, Artemi G. Shmelev, Dmitry K. Zharkov, Anton P. Chuklanov, Niaz I. Nurgazizov (Zavoisky Physical-Technical Institute, FRC Kazan Scientific Center of RAS, Kazan, Russia)

9.50 – 10.10

Vizualization and Probing the Surface of Isolated Nervous System of Grape Snail Using Luminescent Nanoparticles

L.A. Nurtdinova, A.V. Leontiev, A.G. Shmelev, D.K. Zharkov, R.M. Gataullina, E.O. Mityushkin, A.N. Solodov, R.R. Zairov, A.R. Mustafina, V.V. Andrianov, L.N. Muranova, Kh.L. Gainutdinov, A.P. Chuklanov, N.I. Nurgazizov and V.G. Nikiforov (Zavoisky Physical-Technical Institute, FRC Kazan Scientific Center of RAS, Kazan, Russia)

10.10 – 10.30

Multifunctional up- and downconverting fluorescent $NaYF_4:Yb^{3+}/Tm^{3+}$@$NaGdF_4:Ce^{3+}/Tb^{3+}$ nanoparticles

A.V. Leontyev, R.M. Gataullina, A.N. Solodov, L.A. Nurtdinova, A.G. Shmelev, D.K. Zharkov, V.G. Nikiforov (Zavoisky Physical-Technical Institute, FRC Kazan Scientific Center of RAS, Kazan, Russia)

10.30 – 10.45

Linear and nonlinear multivariate fluorescence thermometry with MPy(OPrOH)2 porphyrin

M. Khodasevich, I. Kolesnikov, S. Apanasevich, D. Korolko, M. Kurochkin, Y. Gorbunovac (B.I. Stepanov Institute of Physics, NAS of Belarus, Minsk, Belarus)

10.45 – 11.00

Multimodal temperature sensors based on Er3+/Tm3+/Yb3+ co-doped NaYF4 microcrystals operating in the first window of biological transparency

Evgeny O. Mityushkin, Artemi G. Shmelev, Andrey V. Leontyev, Larisa A. Nurtdinova, Dmitry K. Zharkov, Victor G. Nikiforov (Federal Research Center «Kazan Scientific Center of Russian Academy of Sciences»)

Coffee Break 11.00 – 11.15

Nonlinear spectroscopy and laser-matter interaction 11.15 – 13.05

Physics Department, room 330 (*Chairman O.G.Romanov*)

11.15 – 11.35

Determination of trace amounts of metals in non-metallic matrixes by double-pulse LIBS

K.F. Ermalitskaia, E.S. Voropay (Belarusian State University, Minsk, Belarus)

11.35 – 11.50
Multiplexed recording of dynamic gratings in bismuth silicate crystal by laser pulses
I.G. Dadenkov[1)], A.L. Tolstik[1)], A.V. Pestova[2)], Yu.I. Miksuk[3)], K.A. Saechnikov (Belarusian State University, Minsk, Belarus)

11.50 – 12.05
Determination of the topological charge of a phase singular beam using a nematic liquid-crystal Fresnel lens
Y.P. Pantsialeyeva, E.A. Melnikova (Belarusian State University, Minsk, Belarus)

12.05 – 12.20
Numerical simulation of metal melting within the framework of a two-temperature model
S. Lipski, O. Romanov (Belarusian State University, Minsk, Belarus)

12.20 – 12.35
Simulation of a-Si-Au composite modification by a nanosecond laser pulse
J.V. Shafarevich, A.S. Fedotov (Belarusian State University, Minsk, Belarus)

12.35 – 12.50
Electromagnetic properties of AgNi/MWCNT-PMMA composites in THz range
P. Y. Misiyuk, G. V. Gorokhov, G.V. Golubtsov, M.A. Kazakova (Institute for Nuclear Problems of Belarusian State University, Belarusian State University, Minsk, Belarus; Boreskov Institute of Catalysis SB RAS, Novosibirsk, Russia)

12.50 – 13.05
Superradiance in ultrashort pulse reflection signals taking into account the Bloch-Siegert shift
R. Rusetsky, K. Pistsova, A. Kolesenko, V. Kolesenko (Scientific- Practical Material Research Centre, Minsk, Belarus)

Lunch Break 13.05 – 14.30

High-energy physics 14.30 – 17.00

Physics Department, room 330 (Chairman)

14.30 – 14.50
Tenth order correction to the lepton anomaly from some bubble-type diagram
O.P. Solovtsova, V.I. Lashkevich, L.P. Kaptari (Joint Institute for Nuclear Research, Dubna, Russia)

14.50 – 15.10
Pionic decays of light mesons in relativistic quantum mechanics
V.Yu. Haurysh, V.V. Andreev (Sukhoi State Technical University of Gomel, Belarus)

15.10 – 15.30
Bounds on V – V' mixing from resonant production of extra gauge V' boson decaying into VH at the LHC
Inna Serenkova (Sukhoi State Technical University of Gomel, Gomel, Belarus)

15.30 – 15.50
CNT-assembly enhanced scattering of 60Co-gamma-ray in a detector crystal
H.V. Grushevskaya and A.I. Timoshchenko (Belarusian State University, Minsk, Belarus)

15.50 – 16.05
Model-independent constraints on the mass and couplings of extra neutral boson in the process of e^+e^- annihilation at the ILC and CLIC
D.V. Sinegribov, V.V. Andreev, I.A. Serenkova (Gomel, Belarus)

16.05 – 16.20
Study of rod ejection accidents for VVER-1200 at different initial states using DYN3D code
Ivanton Rudziankou, Leanid Babicheu (JIPNR-Sosny, NAS of Belarus, Minsk, Belarus)

The cultural program 19.00

Friday 27.09.2024

Theoretical and Computional Physics 9.30 – 11.00

Physics Department, room 330 (Chairman G.G. Krylov)

9.30 – 9.50
Nonrelativistic approximation in the theory of a spin 2 particle with anomalous magnetic moment
A.V. Ivashkevich, V.M. Red'kov, A.M. Ishkhanyan (Institute of Physics, National Acad. Sci. of Belarus, Minsk, Belarus)

9.50 – 10.10
Simulation of short-range interaction by means of composition of pseudoharmonic potentials
V.V. Kudryashov, A.V. Baran (Institute of Physics, National Acad. Sci. of Belarus, Minsk, Belarus)

10.10 – 10.30
On the tensor analyzing power component T_{20} for the reaction of incoherent neutral pion photoproduction on the deuteron in □-resonance region
Alexander Fix, Viacheslav Gauzshtein, Elena Kokoulina, Michael Levchuk, Maxim Nevmerzhitsky, Roman Shulyakovsky (Institute of Applied Physics NAS of Belarus, Minsk, Belarus)

10.30 – 10.50
Cylinder with a spherical defect of the "discontinuity" type in an external magnetic field
Alexei Shaplov, Alexander Garkun, Maxim Nevmerzhitsky, Roman Shulyakovsky (Institute of Applied Physics NAS of Belarus, Minsk, Belarus)

Coffee Break 10.50 – 11.20

11.20 – 11.40
Dirac – Kaehler particle in an external magnetic field, cylindrical tetrad and Fedorov – Gronskiy method
A.V. Ivashkevich, V.M. Red'kov (Institute of Physics, National Acad. Sci. of Belarus, Minsk, Belarus)

11.40 – 12.00

Effect of Active Brownian Motion on Dust-Acoustic Instability in a DC Glow Discharge.

A.S. Svetlov, F.M. Trukhachev, E.A. Kononov, M.M. Vasiliev, O.F. Petrov (Belarusian-Russian University, Joint Institute for High Temperatures of the Russian Academy of Sciences, Mogilev, Belarus)

12.00 – 12.15

Influence of the geometry of the pole piece on the performance characteristics of a stationary magnetic fluid seal.

S.G. Sharyna, M.S. Krakov (Belarusian State University, Minsk, Belarus)

12.15 – 12.30

Influence of humidity on electrophysical properties and charge transfer mechanism of nanoscale DLC coatings

I.A. Zur, J.A. Fedotova, A.S. Fedotov, Y.Y. Shmanay, A.K. Fedotov, A.A. Kharchanka, N.I. Gorbachuk, E.A. Ermakova, and S. Movchan (Institute for Nuclear Problems of Belarusian State University, Minsk, Belarus)

12.30 – 12.45

Computer simulations of the thermal stabilization system of the MPD detector of the NICA accelerator complex

A.S. Fedotov, I.A. Zur, M.A. Medvedeva, S.A.Movchan, I.A.Balashov (Belarusian State University, Minsk, Belarus)

Coffee Break, Round Table & Closing 12.45 – 13.00

Acceleration and twisting of neutral atoms by strong elliptically polarized short-wavelength laser pulses

Vladimir S. Melezhik, Sara Shadmehri
Joint Institute for Nuclear Research, Dubna, Russia
melezhik@theor.jinr.ru

We have investigated non-dipole effects in the interaction of a hydrogen atom with elliptically polarized laser pulses of 10^{14} W/cm^2 about 8 fs duration. The study was performed within the framework of a hybrid quantum-quasiclassical approach in which the time-dependent Schroedinger equation for an electron and the classical Hamilton equations for the center-of-mass (CM) of an atom are simultaneously integrated [1]. It is shown that the spatial inhomogeneity $\mathbf{kr}$ of the laser field and the presence of a magnetic component in it lead to the non-separability of the CM and electron variables in a neutral atom and, as a consequence, to its acceleration [1,2]. We have established a strict correlation between the total probability of excitation and ionization of an atom and the velocity of its CM acquired as a result of interaction with a laser pulse. The acceleration of the atom weakly depends on the polarization of the laser in the considered region (5 eV $\lesssim \hbar\omega \lesssim$ 27 eV) of its frequencies. However, the transition from linear to elliptical laser polarization leads to the twisting of the atom relative to the axis directed along the propagation of the pulse (coinciding with the direction of the momentum of the accelerated atom). It is shown that with increasing ellipticity the twisting effect increases and reaches its maximum value with circular polarization, at this point the projection of the orbital angular momentum acquired by the electron onto the pulse propagation reaches its maximum value. Further exploration of the possibilities for producing accelerated and twisted atoms with electromagnetic pulses is of interest for a number of prospective applications.

[1] V.S. Melezhik, Quantum-quasiclassical analysis of center-of-mass nonseparability in hydrogen atom stimulated by strong laser fields. J. of Phys. A56 (2023) 154003.
[2] V.S. Melezhik and S. Shadmehri, Acceleration of neutral atoms by strong short-wavelength short-range electromagnetic pulses. Photonics 10 (2023) 1290.

Photon condensation in non-classical states in the Gauge invariant Dicke Model

N.Q. San [1], O.D. Skoromnik, A.P. Ulyanenkov [2], A.U. Leonau [3], I.D. Feranchuk [2]
[1] *School of Engineering and Technology - Hue University, Vietnam*
[2] *Atomicus GmbH Amalienbadstr. 41C, 76227 Karlsruhe, Germany*
[3] *Deutsches Elektronen-Synchrotron DESY, Hamburg 22607, Germany*
iferanchuk@gmail.com

We investigate the ground state of two physically motivated modifications of the Dicke model. The first modification corresponds to particles whose phase space contains only two states, for example, particles with spin 1/2 or artificially created qubits. The second modification describes two-level systems that arise as a result of truncating the full Hilbert space of atoms to two levels that are in resonance with the electromagnetic field and are described by the gauge-invariant Dicke model. We demonstrate that the behavior of these systems is qualitatively distinct in both cases. In particular, in the first scenario, a phase transition into the state with a non-zero amplitude of the classical field is possible, while in the second case, the so called order parameter $\eta = < a >$ of the field's phase transition into a coherent state with photon condensation is zero. However, the average number of photons $\bar{n} = < a^{+} a > \neq 0$, and the collective excitation in the system manifests a non-classical "squeezed" state of the field. We analyze the observable characteristics of both systems in a wide range of variations of their parameters.

Simuations and Applications of the High-Energy Elecromagnetic Showers in Oriented Crystals

V.V. Tikhomirov, V.V. Haurylavets, A.S. Lobko, M.S. Sachyuka
Institute for Nuclear Problems of Belarusian State University, Minsk, Belarus
vvtikh@mail.ru

The 70-th year history of investigation of the effect of coherent increase in both the radiation intensity and probability of pair production in crystals is reviewed with the emphasis on the prediction and study of synchrotron-like processes by professor V.G. Baryshevsky and his school, which take place10 GeV and higher energies. The effect of acceleration of electromagnetic showers development in crystals is of the widest interest when it manifests itself in crystalline scintillators used in electromagnetic calorimeters of detectors used in high-energy physics and orbital gamma-telescopes. Besides the development of compact crystalline detectors and gamma-telescopes, among the presently studied applications are the production of intense positron beams intended for further acceleration in the designed linear and ring colliders, the process of absorption of gamma quanta by crystals in order to weaken the unwanted background in the experiment to search for a violation of the Standard Model of fundamental interactions in the decays of neutral K-mesons, as well as the use of crystals to facilitate the production of secondary beams of gamma quanta and high-energy positrons at proton accelerators. A newly developed program for the full simulations of high-energy electromagnetic showers in the oriented crystals that combines the methods for describing coherent processes of scattering, radiation, and pair production in a crystal lattice at high energies and small deviations of particle momenta from the crystalline directions with the GEANT4 toolkit algorithms for simulating similar processes in the approximation of an amorphous medium at low energies and large deflections is announced.

Electric field of a charged ring located in the equatorial plane of Kerr black hole

S.O. Komarov, A.K. Gorbatsievich, G.V. Vereshchagin, A.S. Garkun
(Belarusian State University, Minsk, Belarus)

Electric field of a static charged ring that is located in the equatorial plane of Kerr black hole is calculated by numerically solving the Teukolsky equation. Lines of electric force are constructed and its structure analyzed for different values of the radius of the ring, mass of black hole and the angular momentum of black hole. The applications to astrophysical models of active galactic nuclei are discussed.

Studying the properties of ratchet systems by the Green's function method

V.M. Rosenbaum
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The Green's function method is an effective tool that a researcher can use to analyse the properties of systems being disturbed by external perturbations. For ratchet systems, such perturbations are fluctuations of the spatially periodic potential energy of a Brownian particle, which can initiate a particle directed motion. To obtain analytical expressions for the average velocity of an overdamped motion of a ratchet, one should use Green's function of diffusion in a stationary periodic potential and construct a perturbation theory in small fluctuations [1]. Nontrivial frequency and temperature dependences of the average velocity of the ratchet with a stationary sawtooth potential, dichotomously modulated by a spatial harmonic perturbation, were obtained in Ref. [2]. This presentation reports on the obtained Green's function of diffusion in a stationary stepwise potential and the properties of ratchets with various functional forms of dichotomous fluctuations of nanoparticle potential energy. The results obtained clarify what distortions in the shape of the stepwise potential lead to the ratchet motion in one direction or another.

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Bound states in the continuum in non-Hermitian layered structures

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Bound states in the continuum (BICs) are localized nonradiating modes of open resonators providing numerous new effects and applications in modern nanophotonics. In this talk, I start with an overview of optical BIC research and then discuss our recent results aimed at marrying BICs with non-Hermitian photonics. In particular, we consider a PT-symmetric layered structure (system with balanced loss and gain) with the outer layers possessing permittivity near zero. We theoretically show that this system supports PT-symmetry-enabled quasi-BICs which occur in spectra as high-quality resonances with almost perfect transmission and strong light localization and with the non-Hermiticity parameter governing the value of Q factor. Then, we introduce the asymmetry (geometric or non-Hermitian) to the system, which can be used to restore the Q factor of the resonance, and show that the system in this case behaves as a coherent perfect absorber and a laser simultaneously. Moreover, the counter-intuitive effect of loss-induced-lasing is found for the non-Hermitian asymmetry as well. We discuss the topological difference between the quasi-BICs with symmetric profile and the asymmetric Fano resonances in this system showing that they have different winding numbers. Finally, the applications of these BIC-supporting systems to sensing are briefly discussed.

Gluon dominance model and multiplicity distributions of hadrons

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Into frameworks of the gluon dominance model multiplicity distributions of charged particles are described. The main results of the comparison with experimental data are presented.

Modern tools for mathematical modelling of electronic amplifiers and generators of coherent radiation

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We consider the problems arising from the widespread use of ready-made software packages in mathematical modelling of various electronic amplifiers and generators, including volume free electron lasers. Many of such software products are commercial and have a high cost. But even using freely distributed software packages, due to their complexity and insufficient flexibility, significant efforts are often required to configure the input parameters of these codes to obtain adequate results of modelling the physical processes under consideration. Often, researchers, using such complex software packages, try to work without formulating systems of equations describing the physical processes under consideration, trusting the developers. This can lead to some non-physical results. That is why many researchers use their own software packages. The above reasoning is also valid for other areas of mathematical modelling of physical processes. This topic is important for students and postgraduates of physical and mathematical profiles who in the future plan to connect their activities with mathematical modelling of various physical phenomena and devices, as well as for researchers whose task is to study various physical laws using mathematical modelling methods.

Chaotic mappings for images encrypting

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The issues concerning the use of chaotic mappings, including Arnold's cat map, Henon map and the logistic map for encrypting information in the form of images are considered. To demonstrate the capabilities of the aforementioned algorithms, a computer program has been implemented in Phyton. Test images: Horizon Zero.png of size 250x250 pixels, Peppers.png of size 435x435 pixels, Squirrel.png of size 3489x2160 pixels are used.

The developed software has been tested. According to the requirements the histograms of the images and the autocorrelations of the three images used in the work have been defined, the results of which indicate the effectiveness of the proposed program.

Object recognition on heterogeneous backgrounds using hybrid deep learning for spatial inverse problems

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This paper investigates hybrid deep learning-based approaches for object recognition tasks on spatial data with complex, heterogeneous backgrounds, contrasting with one-stage detectors. The study focuses on the semantic imaging of maritime vessels against noisy back-grounds, including sun glares on water, third-party artifacts, and clouds. The approach was evaluated on a pre-processed SPOT satellite dataset and achieved a recognition F2 accuracy of 0.8512. Potential applications for related computer vision tasks, such as object tracking, as well as spatial inverse tasks, such as risk management, are discussed.

Mental Fatigue Induced by Exposure to a WiFi Range Electromagnetic Noise Generator

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The study aims to determine human mental fatigue resulting from exposure to an electromagnetic noise generator operating in the frequency ranges of 2400-2500 MHz and 5150–5350 MHz (Scorpio Suppressor Wi-Fi - 15) with a power of 4 W. To measure and analyze the electroencephalograms of a male participants (31.4 \pm 3.7 years), the "Neuron-Spectrum-4" electroencephalograph from Neurosoft was used. Electroencephalograms were analyzed according to the International "10-20" system in two regimes: regime 1 (baseline) and regime 2 (after exposure to the electromagnetic noise generator). Linear and nonlinear indicators were used as quantitative parameters: spectral power density of delta, theta, alpha, beta, and gamma rhythms, Lempel-Ziv complexity, and sample entropy.

The results of the study showed that 4 parameters confirmed the presence of mental fatigue: Lempel-Ziv complexity, spectral power density of alpha, beta, and gamma rhythms; and 3 parameters contradicted mental fatigue: sample entropy, spectral power density of delta and theta rhythms. This allows us to conclude that human mental fatigue resulting from exposure to the electromagnetic noise generator operating in the frequency ranges of 2400–2500 MHz and 5150–5350 MHz is present.

Topological properties of the optical Tamm states in a one-dimensional chain of microresonators

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Among the important tasks of topological photonics, there are the use of electronic topological insulators as optical materials and the use of photonic topological insulators. These include obtaining topologically stable optical Tamm states and topological states on arrays of vertically emitting microlasers. In this paper, we investigate topological and boundary states in a one-dimensional Su-Schrieffer-Heeger (SSH) lattice of microresonators with a defect in the center. A zigzag lattice can be used as an example, with alternating longitudinal and transverse connections between vertical lasers acting as microresonators. Microresonators at the edges are strongly connected, but the periodic alternation of strong and weak bonds is disrupted by several strong bonds placed in the center for symmetry. We consider finite lattices with an odd number of microresonators for simplicity. The Hamiltonian of the system is a two-diagonal matrix H. The complex coefficients in the Hamiltonian represent the phase shift of the coupling constants. The H matrix is self-adjoint, so its eigenvalues are real. In this paper, we explore the defective and topological modes that arise in the lattices we study. A crucial aspect is the practical realization of a chain with complex couplings.

Machine Learning-Driven Analysis of Carbon Nanotube Accumulation in Cancer Cells via Raman Spectroscopy

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Machine learning offers significant potential for extracting insights from extensive datasets. In this study, we utilized principal component analysis (PCA) and K-means clustering to explore the accumulation of single-walled carbon nanotubes (SWCNTs) in cancer cells. We examined the Raman spectra of cells exposed to SWCNTs capped with either DNA or oligonucleotides (ON) and tracked their temporal evolution. Through unsupervised machine learning techniques, we elucidated the mechanisms and sequences of SWCNT accumulation and distribution in glioma cells, highlighting the chirality discrimination by capping molecules and subsequent selective intracellular transport. PCA facilitated the denoising of Raman spectra and extraction of specific biochemical information, while K-means clustering visualized the distribution of nanotubes and cellular compartments. Utilizing machine learning, we successfully extracted information on carbon nanotube accumulation in cancer cells from Raman spectra datasets, obviating the need for additional research methods.

Self-organization of charged particles in lateral potentials with a high symmetry

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The problem of the optimal configuration of a finite number of particles in a plane has been a difficult problem of both physics and mathematics for many centuries. Back in 1611, Kepler posed the question of why a snowflake has perfect hexagonal symmetry [1]. At present, increased interest in the problem of the optimal configuration is also due to the development of nanotechnologies which make it possible to form systems of similarly charged particles confined by external potentials with a high symmetry. For example, this problem arises when analyzing the behavior of quantum vortices in a Bose condensate [2]; electrons in quantum dots [3]; and the self-organization of colloidal particles at the interface between two different liquids [4, 5].

In this communication we discuss the basic principles of self-organization of one-component charged particles, confined in disk and circular parabolic potentials [6,7]. The main idea is based on the cyclic symmetry and periodicity of the Coulomb interaction between particles located on several rings. Our approach reduces significantly the computational effort in minimizing the energy of equilibrium configurations and demonstrates a remarkable agreement with the values provided by molecular dynamics calculations. With the increase of particle number $n \geq 180$ we find a steady formation of a centered hexagonal lattice that smoothly transforms to valence circular rings in the ground state configurations for both potentials. At the same time, the energetic preferences for nonuniform local density then favor ground states where this locally hexagonal structure is isotropic dilated and contracted throughout the structure. In fact, the equilibrium configuration is determined by the need to achieve equilibrium through the formation of a hexagonal lattice on one side and a ring-like structure on the other. This competition leads to the formation of internal defects in such systems, in contrast to the case of unlimited regions, where the ground state of the system has no defects [8]. Finally, this structure smoothly transforms to valence circular rings in the ground state configurations for both potentials.

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Complex dynamics in Hamiltonian-driven dissipative system

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We study the discrete system that approximates a billiard with oscillating boundaries. It consists of a dissipative 2D map affected by a conservative 2D map. We show that the variety of dynamic regimes including strange non-chaotic exist in this system as well as the multistability with the extreme number of coexisting attractors.

On an approximate formula for functionals with respect to stochastic Poisson measure

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The report proposes a formula for the approximate calculation of mathematical expectations of functionals with respect to a stochastic Poisson measure. The formula belongs to weak methods of approximating the values of functionals and is exact for third-order moments. Examples of application of the formula are given.

Optimizing 3D Ionosphere Reconstruction Algorithm Based on Modified Landweber Method for Enhanced Radiotomography Accuracy

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The report addresses the problem of three-dimensional ionospheric reconstruction using data from global navigation satellite systems. We present a novel algorithm for 3D ionospheric reconstruction based on a modified Landweber method. Key features include setting relaxation parameters and initial values according to the Chapman equation and exponential distribution, smoothness constraints using a nine-point finite-difference approximation of the second-order Laplace operator, and weighting coefficients to account for constraints and initial values. The algorithm structure and operating principle are described. We developed a mathematical modeling framework to investigate ionospheric reconstruction algorithms, utilizing simulated total electron content measurements derived from a realistic ionospheric model. Results show reconstruction quality dependencies on the choice of ionospheric pierce point and weighting coefficients determining smoothness constraints and initial approximations. A methodology for optimizing the 3D reconstruction algorithm parameters, utilizing an ionospheric mathematical model and surrogate multi-parameter optimization is proposed. This approach significantly reduces algorithm tuning time and ensures finding the global extremum. The proposed method advances ionospheric tomography capabilities with potential applications in radio communications, navigation, and space weather monitoring, demonstrating improved accuracy in reconstructing ionospheric electron density distributions.

Geometric Models of Nonwandering Indecomposable Continua

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Recently, I have researched and then announced the topological classification of the Birkhoff curves and the nonwandering continua possessing Wada property. At the same time, I made a fundamental mistake by allowing the existence of more than the only fixed point belonging to the Birkhoff curve.

Theorem 1 Birkhoff curve contains the only fixed point.
K. Kuratowski (1928) proved that an indecomposable continuum cutting a plane into two regions turns out to be monostratic (monostratique) [1]. Therefore, the Birkhoff curve has the only fixed point with an index being equal to zero. It is simple. So that, the Birkhoff curve is consisted to be nonwandering indecomposable continuum turning out to be two invariant regions boundary with respect to dynamic system acting on the plane. The Birkhoff curve geometric model has been constructed based on the Knaster example indecomposable continuum having two composants [2]. Endpoints (0,0) and (0,1) of the Knaster's continuum are glued by the formula $(y-7/20)e^{2\pi x} \mapsto x+iy$.
Now, on the assumption of the principle of constructing the Birkhoff curve geometric model, geometric models of the nonwandering continua turning out to be three regions common boundary have been constructed. The continua turn out to be three regions common boundary. Moreover, these constructions turn out to be more adapted to dynamic systems.

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Dynamic holography for light fields transformation and materials diagnostics of advanced photonics and electronics

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The report presents a review of the theoretical and experimental studies in the field of dynamic holography, its history and the development stages are considered, new trends in its applications in science and engineering are indicated with the use of the obtained results. The classical holography aspects are treated along with the nonlinear-optical approach based on multiwave interaction schemes in the case when the third-order and higher-order nonlinearities are involved. Special attention is given to the use of dynamic holograms for the control of laser beams and for the real-time wave front transformation of light beams, singular including. The techniques to realize the topological charge inversion and multiplexing as well as the frequency transformation of images, showing much promise for 3D image visualization and for data coding when using the light-bean polarization and topological charge as information parameters, have been proposed. New schemes of contactless diagnostics for functional materials have been suggested on the basis of the dynamic grating method. The possibility to separate different nonlinearity mechanisms due to variations in the wave length of laser radiation and in the grating period is shown. The methods of measuring the parameters of bulk and thin-film semiconductors and also of the activated crystals (thermo-optical coefficient, thermal diffusivity, lifetime of the carriers, lifetime of the excited state, and so on) are considered.

A detailed study of the Bragg diffraction on the regular domain structures with inclined walls in 5%MgO:$LiNbO_3$ crystals

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Regular domain structures (RDS) in lithium niobate crystals provide nonlinear transformations of the spectral characteristics of laser radiation in the quasi-phase-matched regime as well as controlling thereof temporal, spatial and polarization parameters with high efficiency. The linear Bragg diffraction on RDS is the nondestructive method to study of their quality and parameters. We report the results of an experimental study and theoretical analysis of Bragg diffraction on RDS with inclined walls in a sample of 5%MgO:LiNbO3 at different positions of the center of an elliptical probe laser beam with a waist size of about 25 μm along the polar Z axis. From the experiments it has been found that the diffraction efficiencies for different spatial harmonics of perturbations of the optical properties created by the walls of the RDS in the crystal are characterized by nonmonotonic behavior. Under theoretical analysis of the observed features of Bragg diffraction we have used an approach based on the Fourier decomposition of dielectric tensor perturbations created by inclined walls of the RDS in discrete spatial harmonics with coefficients determined by the components of the continuous angular spectrum.

Plasmon-Enhanced Optical Nanolithography

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In this report, we propose and investigate a scheme for optical nanolithography of the interference type based on the use of excitation of counter-propagating surface plasmon-polaritons at a flat interface of a metal-dielectric nanostructure. A detailed calculation of the optical nanolithography scheme designed to form sinusoidal diffraction gratings is performed. It is shown that the use of an input prism with a large refractive index allows increasing the gain of the field formed in the photoresist by more than an order of magnitude. The conditions are analyzed for which maximal gain of the field (the penetration depth into photoresist, respectively) and maximal resolution of created gratings are achieved. It is found that by changing the thickness of the layers of the metal-dielectric structure, it is possible to change the wave number at which the plasmon resonance condition is realized, and thereby to control the period of the formed gratings and the depth of field penetration into the photoresist.

The possibility of application of proposed scheme (with certain modifications) for creating two-dimensional and circular gratings, as well as gratings of arbitrary shape is discussed.

Transverse structure of interfering laser beams in canonically conjugate coordinates

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Analysis and control of the transverse structure of laser beams (LB) is an important task, new approaches to the implementation of which are opened by adaptive digital holography. Here, along with highly efficient optoelectronic devices, such as digital cameras and spatial light modulators, numerical methods for processing data on the transverse structure of interfering LB are widely used. The paper considers the implementation of an off-axis scheme for recording the interference pattern (IP) with subsequent discrete Fourier analysis in canonically conjugate coordinates, which allows the IP to be decomposed in the frequency representation into individual components, including those responsible for the formation of the object and phase-conjugate LB. It has been experimentally demonstrated that increasing the IP resolution in frequency coordinates by increasing the Fourier transform array ultimately reaches the resolution level in canonically conjugate spatial coordinates. In this case, decreasing the sampling step in the frequency representation allows resolving the spectral components of the speckle structure detuned from the spectrum of the original LB with greater reliability. It also significantly reduces the error in reconstructing the true phase of the original signal caused by the mismatch between the real value of the carrier frequency and the discrete detuning of the spectral components by ±1 orders, determined with an accuracy of up to one step. It has been shown that analysis and processing of a digital hologram with a high resolution in canonically conjugate coordinates allows reconstructing the wave front of the signal beam with a high degree of accuracy, correcting the interference introduced by both individual optical-electronic units of the holographic system and those formed by the speckle structure.

Nonlinear Resonances in Optoelectronic Artificial Spiking Neuron Based on a VCSEL and SPAD Driven by Periodic Signals and Noise

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Recently, we have proposed an optoelectronic artificial spiking neuron (ASN) based on the pair single photon-avalanche diode (SPAD) – vertical cavity-surface emitting laser (VCSEL) [1]. This type of ASN well mimics basic properties of biological neurons, such as an existence of the threshold and the refractory period, the insensitivity to the effect of the stimuli strength above the threshold, and the dependence of the neuron fire rate of the stimuli strength. On the other hand, this type of the artificial neuron represents an example of the nonlinear threshold dynamical system with probabilistic response and the deadtime. Here we demonstrate occurrence of nonlinear resonances in such a type of the ASN driven by periodic signals and noise. Specifically, we experimentally investigated three kinds of stochastic resonance, namely, for periodic, aperiodic and phantom signals. Similar study was performed for the case when noise was replaced by high-frequency signal resulting in the appearance of periodic, aperiodic and phantom vibrational resonances. The influence of the signal and noise parameters on the peculiarities of stochastic and vibrational resonances in the ASN has been studied. These results can be important from the viewpoint of enhancement of the signal propagation in artificial neurons and networks

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Polarization Instabilities in Vertical-Cavity Surface-Emitting Lasers

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Over the past few years, we have developed a new approach to the description of polarization phenomena in Vertical-Cavity Surface-Emitting Lasers (VCSELs), associated with the phenomenological linear dependence of the anisotropy of gain and/or losses on the value of the injection current density. This approach made it possible to formulate a fairly simple and physically very illustrative interpretation of polarization phenomena in VCSELs, when polarization switching (PS) is deterministic and consists in the transition from one linear polarization to orthogonal polarization through a sequence of partially polarized states. In particular, this approach made it possible for the first time to explain the effect of an anomalous shift in the polarization switching point with an increase in the rate of rise of the injection current. In this report, a more general than linear dependence of gain and/or losses on the value of the injection current density is analyzed. On the basis of a detailed analysis of temperature dependencies, it is shown that the most adequate representation of such a dependence is in the form of a second-order polynomial. The consequence of this dependence is the presence of no more than two PS points in the single mode regimes, the analysis of the numerical simulation results indicates that with a significant shift in PS points, the results in the region of each of them practically do not differ from the case of linear approximation. Therefore, the main attention is paid to the study of the dynamics of polarization effects at a relatively close location of PS points.

Nonlinear properties of biosuspensions

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Different possible scenarios of laser beam propagation in biological suspensions are under study accounting for movement of microparticles under the action of the gradient force of light pressure associated with their polarizability and the forward scattering force, as well as mechanisms of radiation dissipation in matter. To ensure correctness of analysis, we consider the WKB approximation of light scattering. Due to dissipative loses the polarizability of particles can be a complex quantity.

The optical nonlinearity of the suspension is originated from the movement of particles in a field of gradient forces and, as a result, from gradient distribution of biopaticles in medium. This ensures the concentration nature of optical nonlinearity, acting similarly to Kerr nonlinearity and leading to self-focusing of radiation in the medium if the input power of laser radiation exceeds the threshold value. The threshold power is directly proportional to the square of the wavelength and inversely proportional to the square of the particle size. In a steady state, when the influence of diffusion is compensated by the action of gradient forces, soliton propagation of radiation in the biosuspension is possible. The shape of the soliton is determined by the polarizability of the particles, the diffusion coefficient, the mobility and size of the particles, their concentration in the suspension and the effective refractive index of the medium.

Modeling of coherently mode-locked lasers

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Coherent mode-locking represents a promising approach for the generation of ultrashort pulses in lasers beyond the limitations of standard passive mode-locking. This approach is based on the coherent pulse propagation in a laser active medium what allows the production of pulses much shorter in duration than the medium dephasing time. We have performed the detailed modeling of the spatio-temporal dynamics of coherently mode-locked lasers in several arrangements. Besides the numerical solution of Maxwell-Bloch equations, the analytical approach based on the generalized area theorem was developed. Our analysis has demonstrated both the stability and self-starting properties of coherent mode-locking as well as achieving the pulse durations inaccessible by means of standard passive mode-locking.

Jones 4-Spinor and Partially Polarized Light

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We shall present some facts of the theory of the Lorentz group which can be relevant for solving problems of light polarization in the frames of the vector approach by Stokes and Mueller, and by the spinor Jones formalism. A definite correlation exists between completely and partially polarizations of the light and the isotropic and time-like vectors of the Lorentz group.
It is known that for completely polarized light can be described by Stokes 4-dimensional vector or alternatively by Jones complex 2-dimensional vector. The Stokes 4-vector formalism may be extended to a partially polarized light, but Jones approach does not. In the present paper, starting with the Lorentz group theory, we introduce the concept of 4-dimensional Jones spinor, first for a completely polarized light. To such Jones bispinor, there correspond isotropic Stokes 4-vector, and antisymmetric Stokes tensor, the last is equivalent to isotropic complex 3-vector. This approach is extended to the partially polarized light as well. We introduce corresponding 4-spinor of Jones type and 4-vector and antisymmetric tensor of Stokes types. We have introduced the concept of minimal Jones-like 4-spinor, and have found relationships between the relevant Stokes vector and Stokes antisymmetric tensor in analytical form, which is studied numerically as well.

Tunneling times for electromagnetic pulses propagating through a plasma layer

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In present time, tunneling of electromagnetic radiation through media in which the propagation of homogeneous waves is impossible and electromagnetic oscillations are realized in the form of evanescent waves (e.g., through periodic media with photonic forbidden bands and narrowed waveguides) is actively studied. This is due to the possible manifestation in the electrodynamics of the Hartman effect known from quantum mechanics: the tunneling time for a quantum particle is independent of the thickness of the opaque barrier. In the radio wave range, the natural medium that allows modeling this effect is gas discharge plasma, since its permittivity can take negative values. In this work, we performed theoretical estimations of the tunneling time of nanosecond microwave pulse through plasma layer taking into account the electron collision frequency. We used the two approaches to extract the propagation time from our calculations – (i) the time estimated via the pulse center of gravity and (ii) the phase (Wigner) time. We showed that these approaches mostly agree with each other and demonstrate some characteristic features below the plasma frequency. Finally, for experimental verification of the obtained dependencies, we propose the scheme based on nanosecond microwave pulse tunneling through the plasma electromagnetic band gap structure formed by gas discharge plasmas placed in microwave waveguide, in which changing the electronic concentration allows us to switch between the regimes above and below the effective plasma frequency.

Vector magnetometry implemented using 14NV-13C hybrid spin systems in nanodiamonds

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In the modern world, quantum technologies are being actively developed. One of them is quantum magnetometry, in which single nitrogen-vacancy centers (NV centers) in diamond are used as sensors for measuring magnetic fields with nanometer spatial resolution [1]. However, due to the symmetry of the NV center, information about the azimuthal angle of the magnetic field vector is lost. Recently, a method of complete vector magnetometry was proposed [2,3], based on the analysis of experimental spectra of optically detected magnetic resonance (ODMR) of the system NV-13C, in which the electron spin of the NV center is coupled by hyperfine interaction (HFI) with the nuclear spin of 13C.

Here, we simulate ODMR spectra of 14NV-13C systems using HFI matrices calculated by quantum chemistry methods. It is shown that the simulation method ensures the implementation of vector magnetometry. A quantitative description of the ODMR spectra obtained with high spectral resolution in [2] for the 14NV-13C system, in which the 13C atom was the nearest neighbor of the vacancy, is performed. Similar predictive simulation of the ODMR spectra is performed for a number of other NV-13C systems.

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Superferromagnetoresistors

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The strong ferromagnetic nanoparticles are analysed within the band structure based shell model [1] accounting for discrete quantum levels of conducting electrons. As is demonstrated such an approach allows to describe the observed superparamagnetic features of these nanocrystals. Assemblies of such superparamagnets incorporated into nonmagnetic insulator, semiconductor or metallic substrates are shown to display ferromagnetic coupling resulting in a superferromagnetic ordering at sufficiently dense packing. Properties of such metamaterials are investigated by making use of the randomly jumping interacting moments model accounting for quantum fluctuations induced by the discrete electronic levels and disorder. Employing the mean-field treatment for such superparamagnetic assemblies we obtain the magnetic state equation indicating conditions for an unstable behaviour. Respectively, magnetic spinodal regions and critical points occur on the magnetic phase diagram of such ensembles. The respective magnetodynamics exhibit jerky deportment expressed as erratic stochastic jumps in magnetic induction curves. At the critical points magnetodynamics display the features of self-organized criticality. Analyses of magnetic noise correlations are proposed as model-independent analytical tools employed in order to specify, quantify and analyse magnetic structure and origin of superferromagnetism. We discuss some results for a sensor mode application of superferromagnetic reactivity associated with spatially local external fields, e.g., a detection of magnetic particles. Transport of electric charge carriers between superparamagnetic particles is considered as tunneling and the Landau level state dynamics. The tunneling magnetoresistance is predicted to grow up noticeably with decreasing nanomagnet size. The giant magnetoresistance is determined by ratio of respective time of flight and relaxation and can be significant at room temperatures. Favorable designs of superferromagnetic systems for sensor implications are revealed.

[1] V.N. Kondratyev, and V.A. Osipov, Nanomanufacturing. 3, 263 (2023).

On scattering resonances in monolayer and bilayer graphene circular quantum dots

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We analyse in detail eigenstates and possible resonance structure for monolayer and bilayer graphene circular quantum dots within the known massless Dirac pseudo-fermion graphene model. Concept and reasonability of the recently introduced quasi-bound states is also discussed.

Collapse of Klein tunneling resonances in pseudo-Majorana-type pn-graphene junctions

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Strongly correlated many-electron systems whose quasi-particle excitations are subject to non-Abelian statistics are promising for application in quantum devices. Graphene belongs to such systems. A highly efficient Andreev conversion of incident electrons into electron-hole pairs at the interface between graphene-like materials in quantum Hall-effect and superconducting regimes occurs due to hybridization of the quantum Hall edge modes with the states in superconductor [1]. To remain the topologically nontrivial hybridized modes along the edges of the superconducting sample the local and crossed Andreev states should exist on both sides of the superconducting phase. The topological nontriviality of the hybridized modes disappears due to defects and impurities and intensity of the crossed Andreev states is negligibly small also due to the defects. This impedes to design robust quantum processing based on graphene platform However, the local and crossed nontopological Andreev states reside in a superconductor coupled to the two conventional quantum dots [2-4], resulting in SQUID-like oscillations. In our paper we will study a collapse of Klein-tunneling resonances in pseudo-Majorana graphene p-n junctions which are electrically confined graphene quantum dots (GQDs) without physical termination. The p-n graphene junctions are able to support the supercurrent at the superconducting interface along the edges of the sample under conditions of detuning Klein tunneling. To approach it we will elaborate a mechanism for finely tuning collapse of Klein transmission states.

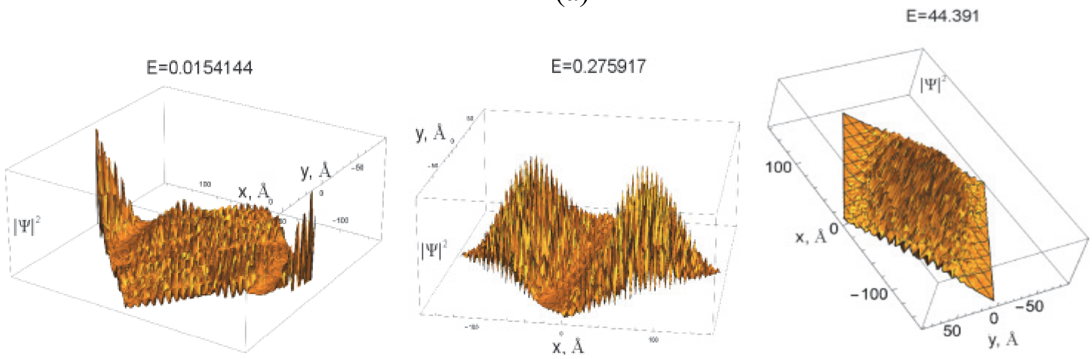
We suppose that graphene quasi-particle excitations are pseudo-Majorana particles. A graphene band structure determined by the pseudo-Majorana Hamiltonian holds electron and hole flat bands where a pseudo-Majorana force (interaction) confines electron-hole pairs in Majorana configurations. We have used the pseudo-Majorana Hamiltonian to describe collapsing Klein-resonances in the graphene p-n junctions. Figure 1 depicts simulation results. As can see, the wave functions for the Klein-tunneling resonances in the toroidal-and spherical-type Majorana GQDs can narrow and the collapse of these transmission states occurs.

States of this kind are lacking in an electrostatically-confined graphene toroidal p−n junction hosting Dirac-Weyl fermions. Dirac-Weyl fermions in the spheroidal GQD can reside on quasi-zero energy levels at any energies because the centrifugal force due to the curvature of the sphere prevents the electrons (holes) from keeping on resonant trajectories. It means that charge carriers of the spheroidal pn junction can escape into bulk graphene, that leads to the pseudo-Dirac-Weyl GQD collapse

Our simulation results in Fig. 1 testify that the pseudo-Majorana force acts similarly to a centripetal (centrifugal) force in the spherical graphene quantum dot. Since the space of the toroidal graphene quantum dot is curved due to the vorticity of graphene electron density, the collapse of Klein-tunneling resonances occurs.

So, the new method for finely tuning Klein-tunneling in pseudo-Majorana graphene p-n junctions is offered. Using this method, collapse of the toroidal Majorana quantum dots was predicted.

(a)



(b)

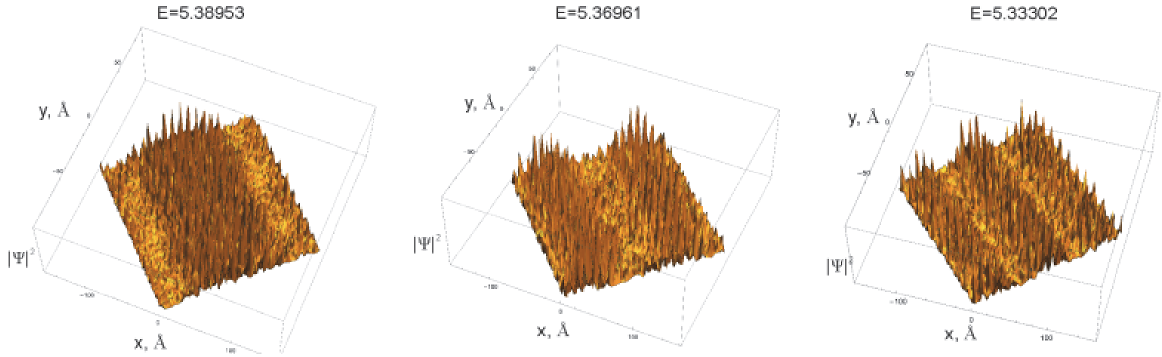


Fig. 1. Collapse of Klein-tunneling resonances in pseudo-Majorana p-n junctions of spherical (a) and toroidal (b) types.

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[2] W. Samuelson et al. Phys.Rev.B. **109**, 035415 (2024).
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[4] K. Wrzesniewski et al. Scientific Reports. **14**, 7815 (2024).

Hybridization of acoustic tamm states with defective mode of a one-dimensional phononic crystal

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Wave propagation in layered media were in the focus of investigated more than fifty years ago, using various mathematical methods to describe propagation of elastic and electromagnetic waves. Currently, a new field of science has been formed to study the properties of photonic crystals and devices based on them. By analogy with the localization of the electronic state near the surface of a solid, it is possible to localize the light wave at the interface of a photonic crystal and the metal or other photonic crystal. This localization is called the optical Tamm state. By analogy with the optical Tamm state, it is also possible to localize an elastic wave at the defect in the phononic crystal. Here we show the results of a study of the spectral properties of a one-dimensional phononic crystal bounded by an air layer. The presence of a defect in a phononic crystal with the air layer leads to a coupling between the defective mode and the acoustic Tamm state. These modes have different nature. The for the spatial distribution manifested mode hybridization, and the repulsions of dips in the reflection spectrum is explained by the avoiding crossing of modes.

Pulse compression and time delay of stimulated Raman scattering components in $Ba(NO_3)_2$ powder

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Temporal compression of stimulated Raman scattering (SRS) components was registered for random Raman lasing in Ba(NO3)2 powder consisting of micron-sized particles. SRS was excited in the 2 mm layer of barium nitrate powder by a Nd:YAG laser second harmonic radiation with a wavelength of 532 nm and pulse duration of 30 ps. Pumping light was focused into the sample. Under this excitation SRS occurred in non-stationary regime. For SRS registration we used monochromator and streak camera with a resolution of 4 ps. We registered radiation at the wavelength of exciting light (elastic scattering), 2 Stokes components and 1 anti-Stokes component. Elastic scattering pulse was longer than exciting pulse (38 ps) and all SRS pulses were shorter: duration of the first Stokes pulse was 32 ps, second Stokes 22 ps and first anti-Stokes 19 ps. Both elastic scattering ans SRS were delayed in time compared to the exciting pulse. It is consistent with the theory of non-stationary regime for bulk media. For the first Stokes component the delay time is few tens of picoseconds and it increases linearly with the increasing of the exciting radiation energy because of the substance nonlinear refractive index growth.

Scalar particle with the Cox structure and polarizability, in presence of the uniform magnetic field

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Within the general method by Gel'fand – Yaglom, starting with the extended set of representations of the Lorentz group, for a spin 0 particle, we construct a relativistic generalized system of the first order equations for a spin 0 particle with two additional characteristics, Cox structure and polarizability. In tensor form, we take into account the presence of external electromagnetic fields. After eliminating the accessory variables of the complete wave function, we derive the minimal 5-component form of equations, the last includes two additional interaction terms which are interpreted as related to Cox structure and polarizability. Applying the matrix form of the derived system we extend this approach to space-time models with pseudo-Riemannian structure within the tetrad method. We specify this equations to the cylindrical coordinates, and in presence of the external uniform magnetic field. After separating the variables, we derive the system of 5 first order differential equations in polar coordinate. This system may be reduced to a second order equation for a primary function, which is solved in terms of the confluent hypergeometric functions. We derive a formula for energy values, it depends on two additional characteristics, Cox structure and polarizability.
We develop alternative method of studying the problem that is based on the method by Fedorov – Gronskiy. Within this approach, the complete 5-component wave function is presented as some of three projective constituents, dependence of each constituent on the polar coordinate is determined by only one function. We find expression for this basic function $F_i(r)$ in terms of confluent hypergeometric equations; at this there arises a quantization rule for some spectral parameter. Within the method by Fedorov – Gronskiy, additionally arises algebraic homogenous system of 5 equations, its solutions determine the structure of 5-component wave functions. From this algebraic system there arises the formula for energy levels, that includes the previously introduced spectral parameter with the known quantization rule. The final formula for energies turns out to be the same for both methods.

Temperature reversal of the ratchet motion direction due to tunnel effect

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We consider a pulsating ratchet with a spatially periodic double-well potential profile undergoing shift fluctuations by half a period. In such a ratchet, the motion direction is determined by the answer the question: “For which of the barriers surrounding the shallow potential well the probability of overcoming is greater?” At relatively high temperatures, in accordance with the Arrhenius law, the probabilities of overcoming the barriers are determined by their heights, and at temperatures close to absolute zero, when the ratchet moves according to the tunnel mechanism, the barrier shapes become important. Therefore, for narrow high and low wide barriers, the overcoming mechanism may turn out to be different and, moreover, dependent on temperature. As a result, a temperature-induced change in the direction of the ratchet motion may occur. We present a simple interpolation theory to illustrate this effect. We also formulate simple criteria for the choice of the shape of the potential relief at which one can experimentally observe motion reversal.

[1] V. M. Rozenbaum, I. V. Shapochkina, L. I. Trakhtenberg. Tunneling mechanism for changing the motion direction of a pulsating ratchet. Temperature effect. JETP Letters **118**, 369 (2023).

Spin 1 Particle with Anomalous Magnetic Moment and Polarizability in presence of the uniform magnetic field

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Within the general method by Gel'fand – Yaglom, starting with the extended set of representations of the Lorentz group, we have constructed a relativistic generalized system of the first order equations for a spin 1 particle with two additional characteristics, anomalous magnetic moment and polarizability. In tensor form, we have taken into account the presence of external electromagnetic fields. After eliminating the accessory variables of the complete wave function, we derive the minimal 10-component form of equations, the last includes two additional interaction terms which are interpreted as related to anomalous magnetic and moment and polarizability. This approach is extended to space-time models with pseudo-Riemannian structure, within the tetrad method. We specify the basic equation to the cylindrical coordinates and tetrad, and in presence of the external uniform magnetic field. After separating the variables, we derive the system of 10 first order differential equations in polar coordinate. To resolve this system, we apply the method by Fedorov – Gronskiy. Within this approach, the complete 10-component wave function is decomposed in three projective constituents, dependence of each on the polar coordinates is determined by only one function. We find expressions for this basic function $F_i(r)$ in terms of confluent hypergeometric equations; at this there arises a quantization rule for some spectral parameter. Within the method by Fedorov – Gronskiy, additionally arises algebraic homogenous system of 10 equations, which completely determines the structure of 10-component solutions. From vanishing the determinant of the algebraic system, we derive a cubic algebraic equation with respect to energy parameter ϵ^2. Its solutions are found in analytical form, and studied numerically.

Hardronic Decays of Heavy Lepton

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Two-particle decays of the τ -lepton: $\tau \to \pi\nu_\tau, \tau \to K\nu_\tau, \tau \to \rho\nu_\tau, \tau \to K^*\nu_\tau, \tau \to a_1(1250)\nu_\tau$ have been studied in the framework of the Quark Confined Model . The obtained branching values are in good agreement with the experimental data. The three-particle decay $\tau \to \pi\pi\nu_\tau$ has been studied. The contribution of the direct diagram and the diagram with the intermediate $\rho(770)$ meson have been considered separately. The obtained numerical value $Br(\tau \to \pi\pi\nu_\tau = 0,237$ is in good agreement with the existing experimental situation.

Leptonic and Semileptonic Interactions of Charmed Mesons

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Within the framework of the Covariant Model of Constituent Quarks (CMCQ), leptonic and semileptonic decays of D mesons have been studied. The widths of leptonic decays

$D \to e\nu_e, \mu\nu_\mu, \tau\nu_\tau$ and the branching fractions of semileptonic decays $D^+ \to \pi^0 e^+ \nu_e, \pi^0 \mu^+ \nu_\mu, K^0 e^+ \nu_e, K^0 \mu^+ \nu_\mu$, $D^0 \to \pi^- e^+ \nu_e, \pi^- \mu^+ \nu_\mu, K^- e^+ \nu_e, K^- \mu^+ \nu_\mu$, $D_s^+ \to K^0 e^+ \nu_e, K^0 \mu^+ \nu_\mu$. The results of calculations within the accuracy of the model are consistent with experimental data and estimates obtained in other theoretical approaches.

Is it possible matching higher-twist contributions with chiral perturbation theory?

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Using the example of the QCD analysis of the precise low-energy data on the polarized Bjorken sum rule, we show how it is possible to make a transition between two regimes of the QCD expansions down to low Q^2 scales. As it is well known, at low momentum transfer, $Q < 1$~GeV, the description of the perturbative part of the Bjorken integral in the framework of standard perturbation theory encounters serious difficulties due to unphysical features of the usual perturbative running coupling. To avoid this difficulty, we use an analytic running coupling which, without introducing additional parameters, eliminates the unphysical features of the perturbative coupling. Since the theoretical description of the Bjorken sum rule involves not only a series in powers of α_s but also a series in powers of $1/Q^2$ (higher twist contributions summing into an unknown function), we will use the technique of matching the function at large Q^2 and behavior at small Q^2 near zero by involving the Gerasimov--Drell--Hearn sum rule. The essence of the ``matching" method is that the sum rule is applied to the region of large values of Q^2, where it works well, and then continues to the region of small Q^2. This allows us to obtain information about the behavior of structural functions in the region where experimental data are not available. The region near $Q^2 = 0$ is of particular interest because it corresponds to small distances between interacting particles. In this region, the structural functions can experience significant changes associated with the manifestation of the inner degrees of freedom of hadrons. A qualitative description of the region near $Q^2 = 0$ can be obtained by analyzing the behavior of structural functions at small values of Q^2. This approach in different loop level of the perturbative part gives a stable good agreement with the experimental data in the whole region up to zero momentum transfer.

Ghost and Gluon Propagators at Finite Temperatures within a Rainbow Truncation of Dyson-Schwinger Equations

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The truncated Dyson-Schwinger and Bethe-Salpeter equations in Euclidean complex momentum domain are analysed within the ladder rainbow truncation. The approach is generalized to finite temperatures. Some critical phenomena in hot matter, such as behaviour of ghost and gluon propagators at high temperatures, relevant to possible signals of Quark Gluon Plasma, are considered.

Matter transport as fundamental property of solitons. Generalization of the Stokes drift mechanism to strongly nonlinear systems.

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A soliton is defined as a nonlinear solitary wave that propagates in environmen t with constant speed, shape and amplitude due to a balance of nonlinearity and dispersion. Solitary wave was first described by J. S. Russell in 1884. The mathematical theory of solitary waves was created by Korteweg and De Vries almost half a century later. The new theory caused a significant stir in the scientific community. Indeed, as follows from the famous equation of Korteweg-De Vries (KdV), the soliton profile has an asymptotic $f(x) \sim \text{sech}^2 x$ for small amplitudes. This means that the soliton remains nonlinear for arbitrarily small amplitudes and does not turn into a linear wave. Further studies have shown that solitons are general phenomenon of nature that describes the properties of nonlinear ion-acoustic waves, magneto-acoustic waves, electric currents in nonlinear transmission lines, and much more. A large number of scientific papers have been devoted to the study of soliton properties, but the physics of nonlinear waves and solitons is far from complete.

The goal of this work is to study the ability of solitary waves to transport matter [1]. On the one side, a soliton is a wave. As expected, material waves do not carry matter (they transfer momentum and energy). It is known that this statement is true only for linear waves of infinitely small amplitude. However, for finite amplitudes waves (even harmonic ones), nonlinear effects lead to the emergence of non-zero drift of matter. This phenomenon was predicted in 1847 by Stokes and was named after him (Stokes drift). As is known, the drift speed for a harmonic wave of small but finite amplitude is proportional to its square. Subsequently, the phenomenon of Stokes drift was repeatedly observed in practice for waves on the water surface, acoustic waves, etc. In the Stokes drift situations, the particle motion represented by a superposition of drift and oscillatory motions. Decrease in the wave amplitude leads to a linearization of the wave process and subsequent rapid (quadratic) decrease in the drift component. In this way, for small amplitude harmonic waves, this nonlinear phenomenon is usually neglected.

In the case of solitons, the nonlinearity cannot be neglected. It is shown theoretically that the unidirectional transport of matter (over a finite distance in the direction of soliton motion) is a fundamental property of KdV solitons. It is also shown that the matter transport cannot be neglected as the wave amplitude decreases (in contrast to the Stokes drift), because the magnitude of the transport decreases in proportion to the square root of the soliton amplitude. Due to the universality of the KdV equation, we expect generalization of our results to a wide range of nonlinear problems.

[1] Phys. Plasmas. 2023. V.30, P.112302.

Half-cycle dissipative solitons in resonant media

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When dealing with a subcycle pulse propagation in a resonant medium, common approximations, such as the two-level model, become invalid due to ultrabroad pulse spectrum. Therefore multiple energy levels in the medium have to be properly considered. We develop the higher-order sudden-perturbation approach to derive the general nonlinear equations for the propagation of subcycle pulses in a multi-level medium. Using these equations, we demonstrate the existense of stable half-cycle dissipative solitons in non-equilibrium media with multiple resonant transitions.

Kosambi-Cartan-Chern geometric invariants, and the structure of the radial differential equations for a Dirac particle in the Newman-Unti-Tamburino space-time

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Applying the methods of differential geometry and technics of Kosambi-Cartan-Chern invariants, we study the radial equations for a spin ½ particle in the Newman-Unti-Tamburino space-time. Starting with the system of two differential equations for massless Dirac particle, we calculate the deviation curvature tensor P^i_j associated with Jacobi stability of the dynamical system. We proof that the real parts of its eigenvalues are positive near the horizon and at infinity, which corresponds to divergence of a pencil of geodesics near these singular points. We construct an effective Lagrangian function associated with this dynamical system. For massive Dirac particle,

we study the relevant system of four radial equations and analyze behavior of eigenvalues of corresponding deviation curvature tensor. We found that the real parts of the eigenvalues are positive near the horizon, but at infinity the eigenvalues tend to $1 - (M / \varepsilon)^2$ / so they are positive for all physically interpreted energy values bigger than the particle mass. The Newman-Unti-Tamburino parameter does not influence on the character of geodesics behavior.

Resonant tunneling in QCD

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Tunneling processes in QCD described by classical solutions of field equations in Euclidean space (instantons) are considered. It has been shown that the exponential suppression of such transitions is removed due to resonance effects. Thus, energy bands are formed by analogy with the effects in crystals. The results are consistent with phenomenological considerations obtained by E. Shuryak, D. Dyakonov and others and also from the analysis of the Shifman–Weinstein–Zakharov (SWZ) sum rule. There are very strong arguments in favor of the fact that instantons in QCD provide the existence of quark and gluon condensates. Moreover, such non-perturbative fluctuations of gluon fields appear enough often. There are very strong arguments in favor of the fact that instantons in QCD provide the existence of quark and gluon condensates. Moreover, such non-perturbative fluctuations of gluon fields appear often enough (the density of instantons is estimated at 1 per Fm^4 in 4-dimensional Euclidean space). So, instanton tunneling transitions will not be suppressed even for medium energies 1 – 10 GeV, i.e. energies that will be achieved at the SPD facility (NICA, JINR). At the LHC accelerator, the range of kinematic regions is much wider, which significantly expands the variability of the task of searching for instantons.

Testing single micro-particles as individual luminescent upconversion probes

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Upconversion nano(micro) crystallites doped with rare earth ions are promising luminescent probes in a wide range of applied and fundamental problems. Particular attention should be paid to the biomedical area: visualization of biological objects, biosensing, therapy and diagnosis of cancer, drug delivery, etc. As a rule, the methods presented in the literature use a large ensemble of upconversion particles. Note that modern confocal optical microscopy makes it possible to detect the luminescent response of single phosphors. Thus, a attractive prospect arises for the development of single particle technology allows one to use an individual probe for monitoring the parameters of the local state of the environment (temperature, viscosity, pH, electric and magnetic fields, etc.). In problems of this kind, the decisive role is played by the features of the photophysical parameters of a single particle chosen as a probe. It should be noted that the parameters of a particle can differ greatly from the values averaged over a large ensemble of similar particles. The report presents studies of the luminescent upconversion response of various single oxide and fluoride submicroparticles, analyzes the multiphoton activation mechanisms of rare earth ions emission and the sourses of luminescence significant polarization. Examples of using single phosphors as temperature and orientation sensors are demonstrated. The prospects for their use in biological objects are discussed.

Vizualization and Probing the Surface of Isolated Nervous System of Grape Snail Using Luminescent Nanoparticles

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Of particular interest is the problem of visualization in biomedicine, when the position of probes introduced into living tissue is registered remotely and noninvasively by optical methods in real time. Simultaneously with visualization of individual organs, luminescent probes can be used for drug transport, selective action on individual areas of biological tissue, in test systems, etc. Nanoparticles $[[Ru(dipy)_3]^{2+}$+@SiO_2, coated with L-cistein molecules, as well as fluoride particles $NaYF_4$:Yb,Er in a SiO_2 shell and $NaYF_4$:Yb,No, coated with PEI polymer were tested as luminescent probes. The Ru-based particles are ~50 nm spheres with a downconversion luminescence mechanism that converts 405 nm laser radiation into visible light with a broad emission band. The fluoride particles are ~200 nm hexagonal plates with upconversion luminescence, when laser light with a wavelength of 980 nm, absorbed by Yb^{3+} ions, is transferred to Er^{3+} and Ho^{3+} ions, which emit in the visible region as well. Using these particles, topographic mapping of living tissues of an isolated nervous system of a grape snail was carried out. Their position in a three-dimensional coordinate system was determined using optical confocal microscopy with a lateral resolution of 10 μm with subsequent mathematical processing. Demonstration experiments were also conducted to measure local temperatures on the surface of individual neurons, accessed using the obtained three-dimensional surface models.

Multifunctional up- and downconverting fluorescent $NaYF_4:Yb^{3+}/Tm^{3+}$@$NaGdF_4:Ce^{3+}/Tb^{3+}$ nanoparticles

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Fluorescent materials with rare earth ions as activators have attracted much interest recently as pure optical probes for the parameters of local environment. We report the synthesis and photophysical analysis of $NaYF_4$:Yb/Er@$NaGdF_4$:Ce/Tb nanoparticles that can be utilized as multifunctional microscopic optical devices.

These core/shell nanoparticles exhibit visible fluorescence both via upconversion process with a quantum yield of 0.19% when excited by infrared light at 980 nm, and downconversion with a quantum yield of 96% upon ultraviolet irradiation at 266 nm. The presence of $NaGdF_4$:Ce/Tb shell was shown to heal defects in $NaYF_4$:Yb/Er core, enhancing the emission of Er^{3+} ions.

As Er^{3+} emission is known to be temperature-dependent these particles could be considered as fluorescent nanothermometers. An experiment illustrating this application was conducted with the nanoparticles spread over unevenly heated surface. The temperature distribution was mapped with 10 μm lateral resolution and 1.6 K accuracy. And as the excitation wavelength falls within biological tissues transparency window these particles could be potentially used as microscopic temperature sensors in living systems. At the same time, these particles could be useful in creating fluorescent inks activated under specific light irradiations, offering novel anti-counterfeiting measures. Furthermore, the presence of Gd^{3+} ions results in MRI contrasting properties, suggesting the use of these kinds of nanoparticles as multifunctional agents in advanced biomedical imaging and sensing applications.

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Linear and nonlinear multivariate fluorescence thermometry with MPy(OPrOH)2 porphyrin

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Fluorescence thermometry is promising to study biological activity down to the subcellular scale with high thermal, temporal and spatial resolution. Previously MPyPP(OH)2 porphyrin was successfully demonstrated as a subcellular ratiometric thermal sensor in different types of cells. In this work the multivariate strategies are applied for temperature calibration with fluorescence spectra of MPy(OPrOH)2 porphyrin from 293 to 318 K with a step of 0.5 K. Spectra were recorded by the Fluorolog-3 modular fluorimeter in the wavelengths range of 540–760 nm. Linear partial least squares method (PLS) and nonlinear support vector regression (SVR) are used for fluorescence thermometry. Multivariate calibration models are trained on the randomly selected subset of fluorescence spectra. Comparison of linear and nonlinear models was carried out by values of the root mean square error RMSE of test subset of fluorescence spectra. RMSE = 0.34 K for wideband linear PLS. SVR is optimized for kernel function (linear, polynomial, Gaussian) that is a method used to transform the input data into the required form. For SVR the best value RMSE=0.31 K corresponds to the linear kernel function. Spectral variable selection by searching combination moving window interval PLS gives RMSE=0.13 K and is the most accurate temperature calibration method among those considered.

Multimodal temperature sensors based on $Er^{3+}/Tm^{3+}/Yb^{3+}$ co-doped $NaYF_4$ microcrystals operating in the first window of biological transparency

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Under near infrared (NIR) excitation upconversion materials doped with rare-earth ions emit infrared, visible and ultraviolet radiation. It is known, that NIR radiation is in the first window of biological transparency (650-1000 nm), which makes upconversion materials promising tools in the field of biology and medicine. One such area is use of upconversion micro/nanoparticles as a probe for non-contact optical thermometry. The non-contact temperature sensor is based on temperature-dependent luminescence properties: excited-state lifetime, position, width, shape and intensity of luminescence peaks, etc. The luminescence intensity ratio (LIR) technique is the simplest and the most accurate. Traditionally, the LIR technique is associated with intensity ratio between two green bands of the emission spectrum of Er^{3+} ions. However, green light is efficiently absorbed by and has limited penetration depth in biological tissues. Therefore, to create effective temperature sensors for biomedical applications, excitation and emission radiations should be localized in the biological transparency window.

The research discusses the prospects of application $NaYF_4:Er^{3+}$, Tm^{3+}, Yb^{3+} upconversion microparticles as temperature and bioimaging probes operating in visible and the first biological window ranges. Er^{3+}/Tm^{3+} doping ions acted as the emitting centers and Yb^{3+} ions acted as the sensitizers. The hexagonal microrods $NaYF_4:Er^{3+},Tm^{3+},Yb^{3+}$ were prepared by means of hydrothermal method using oleic acid as a stabilizing agent. Luminescence (500–900 nm) from $Er^{3+}/Tm^{3+}/Yb^{3+}$ co-doped $NaYF_4$ phosphors were systemically investigated in the 250-350 K temperature range. High temperature sensitivity was achieved by choosing suitable LIR of emissions located in the first biological window. As a result, it was established that intense 805 nm luminescence band of Tm^{3+} ions in $NaYF_4$ upconversion microparticles is optimal for temperature probing for bioimaging applications.

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Determination of trace amounts of metals in non-metallic matrixes by double-pulse LIBS

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The features of single-pulse and double-pulse laser ablation of porous inhomogeneous nonmetallic matrices have been studied. The influence of the matrix on the propagation and excitation of metal atoms in an ablation plasma excited by single and double laser pulses with microsecond interpulse intervals is assessed. Methods have been developed for qualitative, semi-quantitative and quantitative express analysis of porous non-metallic samples containing trace amounts of metals using laser atomic emission spectroscopy using a double-pulse laser spectrometer developed at the Department of Laser Physics and Spectroscopy, Faculty of Physics, BSU.

Multiplexed recording of dynamic gratings in bismuth silicate crystal by laser pulses

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Multiplex recording of holograms is a good method of storage and processing of optical information. The property of holograms, which makes it possible to record in a small volume a large amount of information about incident optical beams, makes it possible to obtain a high density of data on a small volume and to recover a particular hologram independently of the others.
In this work, a photorefractive crystal of bismuth silicate was used as a material for recording holograms. It belongs to the sillenite group and is a wide-gap dielectric with a large number of impurities and structural defects. The presence of the latter leads to the emergence of trap levels in the forbidden zone, recombination of electrons on which leads to the formation of holograms. The obtained holograms are dynamic, i.e. disappear with time and, due to the levels in the forbidden zone, can be obtained using radiation in the visible region of the spectrum.
Multiplexed holograms in bismuth silicate were recorded using the second harmonic of a pulsed Nd:YAG laser, and recovery was performed using a continuous 660 nm semiconductor laser. Laser pulses in the crystal formed holographic gratings with periods of 500 nm and 5 μm, respectively, and an additional delay was created between the beams recording the gratings in order to exclude the formation of additional cross gratings.

Determination of the topological charge of a phase singular beam using a nematic liquid-crystal Fresnel lens

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Currently, many scientific groups are engaged in the study of phase singular beams carrying orbital angular momentum due to the active use of topological charge for the implementation of qudits (multilevel quantum states) in cryptography, quantum information and communication. A simple interference method for analyzing the phase topology of optical vortices based on the preliminary diffraction of singular light beam on an achromatic electrically controlled nematic liquid crystal cell, which is a Fresnel zone plate, is proposed and implemented here. The efficiency of the method has been tested experimentally and theoretically in the visible and near-infrared range. The use of an electrically controlled achromatic Fresnel lens based on a nematic liquid crystal in singular optics offers a promising method for determining the topological charge of a phase singular light beam due to the possibility of analyzing signals coming from free space in real time without changing the circuit based on the possibility of switching on/off the proposed element. The developed method will help expand the scope of application of phase singular beams and significantly simplify existing technologies.

Numerical simulation of metal melting within the framework of a two-temperature model

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Physical, mathematical and 3D numerical models of laser-induced heating and melting process of metals have been developed. Simulations have been performed is the framework of a two-temperature model (for electron gas and ion lattice) and can be used to describe the melting process of metals under action of ultrashort (femto- and picoseconds) laser pulses with various spatial structures. The nonlinear dependence of the thermophysical parameters of the electron gas and ion lattice on temperature is also taken into account in the numerical calculations.

Simulation of a-Si-Au composite modification by a nanosecond laser pulse

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This study considers the numerical modeling of laser heating of composites and is conducted to analyze the temperature dynamics in thin films of amorphous silicon with a 130 nm thickness, with and without a 30 nm gold layer. Using finite difference methods to solve the heat conduction equation, the study examines how laser radiation parameters, with a wavelength of 1064 nm and a pulse duration of 10 ns, affect the heating process. For a 0.5 mm^2 area and the specified laser parameters, the threshold intensity at which material modification begins aligns with experimental data. Results highlight the gold layer's important role in enhancing heat distribution and improving crystallization. This study will aid in optimizing laser parameters for the experimental synthesis of nanocrystalline silicon via metal-assisted crystallization.

Electromagnetic properties of AgNi/MWCNT-PMMA composites in THz range

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In this work the electromagnetic properties of AgNi/MWCNT-PMMA composites, obtained by coagulation precipitation of polymethyl methacrylate and multi-walled carbon nanotubes modified with AgNi nanoparticles, were observed in terahertz frequency range (0.1–1 Thz). That composites are perfect candidates as EMI shielding materials in microwave range, so their investigation in THz range is promising for various shielding applications in this range.

It was shown, that modification of MWCNTs with AgNi nanoparticles led to a decrease in percolation threshold and an increase in conductivity and shielding effectiveness in broadband frequency range. At the same time, the real part of permittivity is decreasing from 8 to 5 while the conductivity is increasing from 35 to 135 Sm/m with increasing frequency from 0.2 to 1 THz. The most effective filler is 100 % Ag, due to its higher conductivity compared to Ni nanoparticles. Thus, AgNi/MWCNT-PMMA are promising for THz applications, in particular, as EMI shielding materials.

Superradiance in ultrashort pulse reflection signals taking into account the Bloch-Siegert shift

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The effect of sample thickness and Bloch-Siegert shift on the reflection signal of resonant ultrashort pulses is investigated. In particular, the superradiance that is formed in this signal is studied. To take into account the effect of the Bloch-Siegert shift, numerical methods for solving the Maxwell-Bloch equations without the rotating wave approximation were used. It is demonstrated that in thinner samples, superradiance is formed at shorter times. It is found that one of the factors that affects the moment of formation of the superradiance maximum is the Bloch-Siegert shift, since it prevents a complete inversion of the two-level system when exposed to a π pulse.

Tenth order correction to the lepton anomaly from some bubble-type diagram

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Analytical expressions for the tenth-order electromagnetic correction to the lepton ($L = e, \mu, \tau$) anomaly, a_L, are derived explicitly for the Feynman diagram involves the vacuum polarization insertion of four closed lepton, three of which are formed by a lepton L of the same kind as the external one. A method based on consistent application of the dispersion relations for the polarisation operator and the Mellin--Barnes transform for propagators of massive particles, was presented in our previous papers. The result is expressed in terms of the mass ratio $r = m_\ell / m_L$. From the exact analytic expressions we find the asymptotic expansions at $r \to 0$ and $r \to \infty$ and compare them with the corresponding expansions known in the literature. We estimate the interval for the mass relation in which the approximate expansions practically coincide with the exact formulas.

Pionic decays of light mesons in relativistic quantum mechanics

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In relativistic quantum mechanics based on point form of Poincare-invariant quantum mechanics obtained the integral representation of $V^{\pm} \to P^{\pm}\pi^{0}$ decay constant. It's shown that soft pion theorem usage leads to the numerical results for $\rho^{\pm} \to \pi^{\pm}\pi^{0}$ and $K^{*\pm} \to K^{\pm}\pi^{0}$ decays consistent with modern experimental data. As a result, self-consistent approach for light meson observed characteristic calculation is proposed.

Bounds on V – V' mixing from resonant production of extra gauge V' boson decaying into VH at the LHC

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The full ATLAS and CMS Run 2 datasets with time-integrated luminosity of 139fb $^{-1}$ and 137 fb $^{-1}$ in the diboson channels are used to probe benchmark models with extended gauge sectors such as E_6, left-right symmetric (LR) and the sequential standard model (extended gauge model, EGM), that predict the existence of neutral Z'- and charged W'-bosons decaying to a pair of bosons ZH and WH in the semileptonic final state. Exclusion limits at the 95% C.L. on the Z' and W' resonance production cross section times branching ratio to electroweak gauge boson pairs in the resonance mass range between 1.0 and 5 TeV are here converted to constraints on Z-Z' and W-W' mixing parameters and masses. We present exclusion regions on the parameter spaces of the Z' and W' and show that the obtained exclusion regions are significantly extended compared to those derived from the previous analysis performed with Tevatron data as well as with the CMS and ATLAS data collected at 7 and 8 TeV in Run 1. The reported limits are the most restrictive to date.

CNT-assembly enhanced scattering of ^{60}Co-gamma-ray in a detector crystal

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Currently, ionizing-radiation detectors which are capable of recoding so-called escape peaks with high accuracy are developed. On the one hand, it allows to use intermediate-size detectors to design high-performance gamma-ray-radiation spectrometers for prospective nuclear applications. On the other hand, it allows to clarify the nature of nuclear decays with creation of electron-positron pairs. The pairs under an electric field action are produced by γ-rays emitted in electron transitions. The high-energy gamma rays converted into an electron-positron pair in the presence of a charged particle feature a beta decay of ^{60}Co into ^{60}Ni. The decay is accompanied by the emission of two gamma quanta with energies, $E_{1.173}$ and $E_{1.334}$, equal to 1.1732 and 1.3324 MeV, respectively. The low-intensity single and double escape peaks, from one and two escaping annihilation photons, respectively, are located at 826.06 and 347 keV, respectively, in an insulator crystal detector response on the ^{60}Co 1.332-MeV gamma ray [1,2]. The single and double escape peaks being recorded by high-purity Ge semiconductor detector are located at 817.6 and 306 keV, respectively [3]. These experimental evidences about the pair-production events are inconsistent with each other. Moreover, the values deviate significantly from the theoretical predictions equal to $E_{1.334} - 2\, m_e c^2$ = 821 keV and $E_{1.334} - m_e c^2$ = 310 keV for single and double annihilation-photon escaping, respectively. Here c is the light speed, m_e is the electron mass. The single and double escape peaks from the pair production by 1.173-MeV photon were not detected. An explanation of this phenomenon is absent. It is possible to increase the resolution by using perfect scintillation crystals and high-purity semiconductors which are capable of recording low-intensity escaping gamma- and X- rays. Today, this problem is unsolvable still. In this report, we will use an single-walled carbon nanotube assemblies (CNT assemblies) to enhance a response of NaI(Tl) detector crystal on gamma-rays from a low-intensity ^{60}Co ionized-radiation source.

Our goal is to reveal and study an enhancement of scintillation-detector response on ^{60}Co ionized-radiation after interaction of the ^{60}Co γ-rays with the CNT assemblies

CNT assemblies were fabricated using Langmuir–Blodgett nanotechnique by depositing two monolayer of single-walled carbon nanotube on a nanoporous aluminium-oxide support. Then the sample was arranged in the detector collimator. Impact of CNTs on ^{60}Co γ-rays passage is in enhancement of both full-energy peaks (photopeaks) and escape peaks. Figure 1 depicts the experimental evidences of CNT-assembly enhanced scattering of ^{60}Co γ-ray in the detector crystal. Radiation vortical defects emerge in a result of the interaction of γ-ray with CNTs.

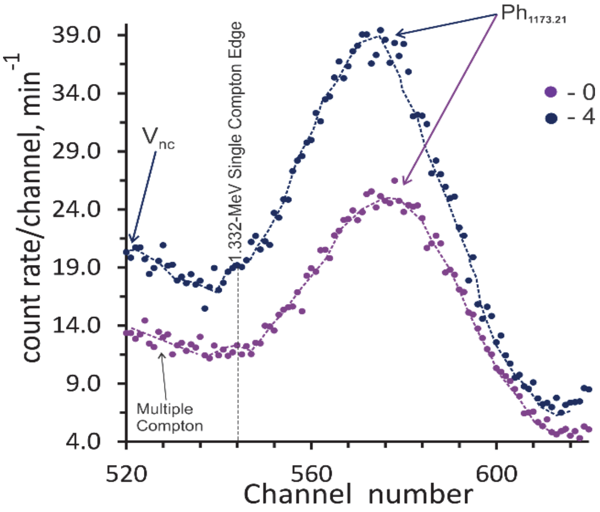

Fig. 1. Photopeak and Single Compton edge in 1.332-MeV-γ-ray spectra recorded by the two scintillation detectors: NaI(Tl)- and NaI(Tl)/CNT-crystal systems. The enhanced 1.332-MeV-γ-ray-backscattering event and the 1.1732-MeV-energy deposition in detector are observed in the radiation dark-blue spectrum ``4'' recorded by the 2nd detector. The responses on these events being recorded by the 1st detector in the violet spectrum``0'' are weak. The peak of deposition of full 1.1732-MeV photon energy is labeled by $Ph_{1.17321}$; a peak attributed to vortical CNT defect is denoted by V_{nc}.

So, a new ^{60}Co IRS-detecting method based on CNT-assembly platform is offered. It is demonstrated that the method is capable of recording low-intensity flows of escaping photons.

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Model-independent constraints on the mass and couplings of extra neutral boson in the process of e^+e^- annihilation at the ILC and CLIC

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Heavy neutral gauge boson Z' are predicted by many theoretical schemes of physics beyond the Standard Model, and intensive searches for their signatures will be performed at future high energy e^+e^- colliders. In this paper, we have obtained model-independent constraints on the Z' mass and couplings for the ILC and CLIC experiments.

Study of rod ejection accidents for VVER-1200 at different initial states using DYN3D code

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Control rod ejection is transient accident that could occur during different states of NPP campaign and lead to overheat in the core of NPP. There is a significant difference in behavior for various initial states such as control rod ejection at full power or hot zero power state of NPP.

Thus such cases meant to be examined separately, especially if one also changes fuel gap in fuel element. One of the most important values to be estimated is DNBR – departure from nucleate boiling rate that show how close one come to incident with uncontrollable overheating of fuel rods due steam blanket insulating.

In this paper we study and examine its behavior at different initial states of NPP and fuel rod fuel gap during control rod ejection in VVER-1200.

Nonrelativistic approximation in the theory of a spin 2 particle with anomalous magnetic moment

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We start with the 50-component relativistic matrix equation for a spin 2 particle in presence of external electromagnetic fields. This equation describes the particle with anomalous magnetic moment, the complete wave function consists of 2-rank symmetric tensor and 3-rank tensor symmetric in two indices. We apply the general method for performing the nonrelativistic approximation, which is based on the structure of the 50×50 matrix Γ^0 of the main equation. With the use of the 7th order minimal equation for matrix Γ^0, we introduce three projective operators. They permit us to decompose the complete wave function into the sum of three parts, one is large, and two other are small in nonrelativistic approximation. We have found independent 5 large variables, and 45 small ones. In order to simplify the task, by eliminating the variables related to the 3-rank tensor we have derived relativistic system of 2nd order equations for 10 components related to symmetric tensor, and then take into account decomposition of these 10 variables into linear combinations of large and small ones. In accordance with general method, we separate the rest energy in the wave function and specify the orders of smallness for different terms in arising equations. Further, after performing the needed calculations, we derive the system of 5 linked equations for 5 large variables. It is presented in the matrix form which has the nonrelativistic structure, where the term of additional interaction with external magnetic field through 3 spin projections is presented. The multiplier before this interaction contains the basic magnetic moment and an addition due to anomalous magnetic moment. The last characteristics is a free parameter of the theory. The final form of this nonrelativistic equation is $i(\partial_t + ieA_0)\Psi = -\frac{1}{2M}\Delta L + \frac{e}{2M}(1+3A^2)(F_{23}S_1 + F_{31}S_2 + F_{12}S_3)\Psi$. where S_i are 5-dimensional spin matrices, F_{ij} stands for external magnetic field, and A^2 is an arbitrary parameter; at $A = 0$, this equation refers to spin 2 particle without anomalous magnetic moment.

Simulation of short-range interaction by means of composition of pseudoharmonic potentials

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The spherically symmetric short-range interaction for the physical system with a finite number of discrete energy levels is simulated with the help of smooth confinement potential of new type which is constructed by means of composition of pseudoharmonic potentials. The exact wave functions and energy levels are found. The dependence of energy spectrum on potential parameters is investigated.

On the tensor analyzing power component T_{20} for the reaction of incoherent neutral pion photoproduction on the deuteron in Δ-resonance region

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In the framework of the diagrammatic approach, we calculate the tensor analysing power component T_{20} for the reaction $\gamma d \to \pi^0 np$ in Δ-resonance region. The contribution of diagrams corresponding to the plane-wave impulse approximation, nucleon-nucleon final state interaction, and pion-nucleon final state interaction is taken into account. We present a comparison of our predictions with other theoretical results and corresponding experimental data.

Cylinder with a spherical defect of the "discontinuity" type in an external magnetic field

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We consider a cylinder in an external magnetic field with uniform magnetization along the axis of the cylinder and with an arbitrarily located small spherical defect of the discontinuity type. We obtain the magnetic field created by such a cylinder and compare it with the field of a cylinder without a defect, which is of interest for problems of determining the location of hidden defects of the discontinuity type.

Dirac – Kaehler particle in an external magnetic field,
cylindrical tetrad and Fedorov – Gronskiy method

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16-component system of equations describing the Dirac -Kaehler particle in presence of the external uniform magnetic field has been studied. This equation describes a multi-spin boson field equivalent to the scalar, pseudoscalar, vector, pseudovector, and anti-symmetric tensor. On the searched solutions, we diagonalize operators of the energy, third projection of the total angular momentum, and the third projection of the linear momentum. After separating the variable, we derive the system of sixteen first order differential equations in the polar coordinate. To resolve this system, we apply the method by Fedorov – Gronskiy based on projective operator constructed from generator J^{12} for the field under consideration.

According to this approach, we decompose the complete wave function into three 16-dimensional projective constituents, each expressed trough only one functions of the polar coordinate. In the present system, these five basic function are constructed in terms of the confluent hypergeometric functions, at this a quantization rule follows from the polynomial requirements. The 16-dimensional matrix structure of projective constituents is determined by the arising linear algebraic system of equations. So, we have found five independent solutions for the Dirac–Kaehler particle in the magnetic field, $\Psi_{\epsilon km\sigma}(t,r,\phi,z)$. The number 5 for independent solutions correlates with 5 different tensor entering the complete wave function for Dirac – Kaehler particle.

Effect of Active Brownian Motion on Dust-Acoustic Instability in a DC Glow Discharge

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Active Brownian particles are particles capable of converting environmental energy into their own motion energy. Active particles can move both independently and exhibit a collective character. The mean kinetic energy of active particles can significantly exceed the mean kinetic energy (temperature) of the environment, which indicates a significant nonequilibrium of the process. Examples of active particles are many bacteria, mobile cells, micro- and nanorobots, dust particles in discharge plasma and superfluid helium.

The influence of active Brownian motion induced by laser impact of different intensity on dust-acoustic instability developing in a plasma-dust cloud consisting of Janus particles is experimentally investigated. The experiment is carried out in a DC glow discharge. In the initial condition, dust-acoustic instability developed in the cloud and reached a strongly nonlinear stage. Illumination with a low-power laser is used to record the wave process. With increasing laser intensity, a change in the dynamics of dust particles, deformation of the cloud, and suppression of the dust-acoustic wave are observed. The wave attenuation is accompanied by a decrease in the longitudinal component of the kinetic energy. Thus, in the considered case, "laser cooling" of the plasma-dust structure isrealized. The analysis of the trajectories of dust particles revealed their characteristic features corresponding to different intensities of laser radiation.

Influence of the geometry of the pole piece
on the performance characteristics of a stationary magnetic fluid seal

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A numerical simulation of the diffusion of magnetic nanoparticles in a motionless magnetic fluid seal (MFS) has been carried out in this work. Two geometries of magnetic fiekd concentrator are considered: triangular and rectangular.

Under the influence of a high-gradient magnetic field, the concentration of magnetic particles in the gap increases significantly. With increasing concentration, the viscosity increases, which leads to a loss of fluidity in the liquid. This, in turn, can lead to problems in the MFS operation.
The aim of this work is to determine the influence of the pole piece geometry on the time at which the magnetic fluid loses its fluidity in the gap of the magnetic fluid seal.
The magnetic field is described by magnetostatic equations. The processes of diffusion and magnetorrhoesis are described by a transfer equation, where a concentration-dependent diffusion coefficient is used.
Based on the formula for viscosity concentration dependence, an expression for describing the relative mobility of particles is proposed. The problem is solved numerically using the control volume method on a triangular mesh.
The numerical calculations allowed us to obtain the distribution of the concentration and viscosity of the magnetic fluid under the polar pieces of different geometries.
The time during which the magnetic fluid loses its fluidity has been determined. Comparing the different geometries of the pole pieces shows that with a triangular geometry, this time is longer than with a rectangular geometry.

Influence of humidity on electrophysical properties and charge transfer mechanism of nanoscale DLC coatings

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The investigation of nanoscale diamond-like carbon (DLC) coatings on acrylonitrile butadiene styrene plastic substrates revealed a linear voltammetric characteristic, a decrease in resistivity from 12 Om•m to 3 Om•m, and a decline in wetting angle from 52° to 38° with increasing thickness from 54 nm to 71 nm. The relative permittivity of the DLC coatings takes values from the range of 5.6...6.5, and in the high frequency limit is completely determined by the real part. It is proposed to consider the conductivity in the system "DLC-coating//adsorbed layer of H_2O molecules" as a combination of two mechanisms: the hopping conductivity of electrons in the volume of the DLC-coating and the proton conductivity by the Grotthuss mechanism in the adsorption layer of water molecules. It has been experimentally established that the variation of air humidity in the range of 16% to 95% leads to a decrease in the resistance of the system up to 10^3 times. The results demonstrate the potential for developing a humidity sensor based on a DLC-coating with a thickness of approximately 50 nm. This technology will be applied in the fabrication of GEM-detectors with resistive coating of the collector electrode.

Computer simulations of the thermal stabilization system of the MPD detector of the NICA accelerator complex

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The NICA (Nuclotron-based Ion Collider Facility) accelerator complex of the Joint Institute for Nuclear Research (JINR, Dubna) is a new collider complex aimed at studying the properties of matter and the processes of collision and birth of new particles with subsequent detection and identification of the latter. Within the framework of NICA project, development is underway to create the MPD (Multi-Purpose Detector) facility for detecting high-energy beam collision products using the TPC (Time-projection chamber), ECal (Electromagnetic Calorimeters) and other subdetectors. During functioning of the MPD facility, heat generated by the detector electronics may lead to a deviation of the thermal stabilization of the working gas volume and, as a result, negatively affect the accuracy of event detection. To control heat generation on the TPC and ECal subdetectors, the MPD is equipped with a water cooling system for electronics and thermal stabilization of the TPC working gas volume. The report describes the design features of the MPD cooling system. The 3D finite element model of the cooling system was developed and numerical calculations of the coolant flow through it were performed. The results of the numerical experiment were verified using data obtained from a full-scale experiment on a specially designed stand.

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