ПЕРСОНАЛІЇ, ХРОНІКА, БІБЛІОГРАФІЯ
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СЕМІНАР ІЗ СУЧАСНИХ ПРОБЛЕМ ФІЗИКИ
(Львів, 5–9 липня 2010 року)

WORKSHOP ON CURRENT PROBLEMS IN PHYSICS
(Lviv, 5–9 July 2010)

On 5–9 July 2010, the Physics Faculty of the Ivan Franko National University of Lviv hosted the Workshop on Current Problems in Physics. The representatives from the scientific institutions of Ukraine and Poland participated in the Workshop and delivered talks on quantum mechanics, condensed matter physics, statistical physics, astrophysics, and some other subjects. The abstracts of the presentations are given below.

UNITARITY AND NEUTRAL MESONS SUBSYSTEM

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We analyze the proof of the Khalfin's Theorem for the neutral meson complex. Some consequences of this Theorem are discussed: using this Theorem we found, e. g., that diagonal matrix elements of the exact effective Hamiltonian for the neutral meson complex cannot be equal if the CPT symmetry holds and the CP symmetry is violated. The properties of time evolution governed by a time-independent effective Hamiltonian acting in the neutral mesons subspace of states are considered. By means of the Khalfin's Theorem we show that if such Hamiltonian is time-independent then the evolution operator for the total system containing neutral meson complex cannot be the unitary operator. Within the given model we examine numerically the Khalfin's Theorem. We show for this model in a graphic form of how the Khalfin's Theorem acts. We also show for this model how the difference of the mentioned diagonal matrix elements of the effective Hamiltonian varies in time.

ON THE CONFINEMENT INTERACTIONS IN PARTIALLY REDUCED YUKAWA-LIKE MODELS

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A modified variational method for deriving relativistic few-body wave equations for interacting matter fields is proposed. The mediating field of the theory is eliminated from the classical Lagrangian in terms of the covariant Green function and particle currents. The reformulated Lagrangian contains time-nonlocal interaction terms and thus it represents a kind of nonlocal field theory. The transition to the Hamiltonian formalism is implemented within an approximation scheme, on account of the time nonlocality.

The system is quantized canonically. The few-particle channel function is used as variational trial function to derive relativistic few-particle integral wave equation with a kernel, which includes the 4D Fourier transform of the covariant Green function. The non-relativistic limit of this equation is shown to be a Schrödinger equation. The corresponding interaction potential is completely determined in terms of a primary Green function.

We apply this approach to the Yukawa model and consider generalizations based on nonstandard field-theoretical models. One of these is a higher-derivative model which yields the linear two-particle potential in the non-relativistic limit. Another example is a nonlinear-mediating-field generalization of the Wick–Cutkosky model, partially reduced by means of an iterative eliminating procedure. In low-order approximations of φ^3 theory we obtain the usual two-particle interaction as well as a three-particle interaction of a confining type. The corresponding relativistic potential, after some regularization, reveals a logarithmic asymptotics.

QUANTUM CHAOS INDICATORS FOR KERR-LIKE OSCILLATORS SYSTEMS

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There is still a considerable interest in quantum physics systems that can demonstrate chaotic motion. Therefore, it is vital to find strict quantum indicators that would determine whether the system has already reached chaotic regions in its dynamics or not. In particular, there is a need for finding quantum parameters playing the role of indicators of chaos appearing in quantum systems. One of such indicators can be *fidelity* calculated between the unperturbed wave-function and that which is a subject of tiny perturbation. As has been shown, short-time behaviour of this parameter can indicate whether the system behaves chaotically or not [1–3]. Contrary to these papers, the main aim of the considerations presented in this communication is to analyse the long-time behaviour of the *fidelity* [4]. In particular, we concentrate on the applicability of both: *fidelity* and fidelity-based entropy, for distinction between regular and chaotic dynamics of the quantum system. Discussing the system of the kicked nonlinear oscillator we shall show that the long-time behaviour of *fidelity* and other fidelity-based parameters defined here (they are of strictly quantum nature) can exhibit its chaotic nature in classical sense. Moreover, we propose a Wigner-function-based parameter that can be used as an indicator of quantum chaos, as well. This parameter is defined as "entropy" from the time dependence of *nonclassicality* proposed by Kenfack and Życzkowski [5]. Performing considerations for the system of damped nonlinear Kerr-like oscillator excited by a series of ultrashort external pulses we show that such defined entropic parameter can be appled as quantum chaos indicator [6].

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SELF FORCE IN $2+1$ ELECTRODYNAMICS AND SELF FORCE ON A POINT-LIKE SOURCE COUPLED WITH MASSIVE SCALAR FIELD

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The radiation reaction problem for an electric charge moving in flat space-time of three dimensions is discussed. The divergences stemming from the pointness of the particle are studied. A consistent regularization procedure is proposed, which exploits the Poincaré invariance of the theory. An effective equation of the motion of a radiating charge in an external electromagnetic field is obtained via the consideration of energy-momentum and angular momentum conservation. This equation includes the effect of the particle's own field. The radiation reaction is determined by the Lorentz force of point-like charge acting upon itself plus a non-local term which provides finiteness of the self-action.

The regularization procedure is applied to the problem of radiation reaction force experienced by a scalar charge moving in flat spacetime. Radiative parts of Noether quantities carried by a massive scalar field are extracted. Energy-momentum and angular momentum balance equations yield the Harish–Chandra equation of motion of a radiating charge under the influence of an external force. This equation includes the effect of the particle's own field. The self-force produces a time-changing inertial mass.

SPECTRAL PROPERTIES OF QUANTUM SYSTEMS WITH SHORT RANGE POTENTIALS

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The talk belongs to the line of research often called singular potentials. The problem is addressed to quantum systems governed by the Schroedinger operator with (singular) potentials localized on very small sets. We study some spectral properties of these systems, for example structure of spectrum, resonaces, etc.

MODIFIED PERTURBATION THEORY FOR HYDROGEN ATOM IN A SPACE WITH THE LORENTZ-COVARIANT DEFORMED ALGEBRA WITH MINIMAL LENGTH

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We study the energy spectrum for the hydrogen atom problem in the Dirac theory with the Lorentz-covariant deformed algebra leading to minimal length. Developing a divergence-free perturbation theory we calculate corrections to any energy level in a simple case when one deformation parameter vanishes. Assuming that the effect of minimal length on the energy spectrum cannot yet be seen experimentally we find the upper bound of minimal length.

ROUTES TO THE THEORY OF SUPERIONIC CONDUCTITITY

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We present various modelling approaches [1,2] to describe protonic conductivity of superionic crystals [3]. The focus is on the potential of the crystal structure with particular emphasis on the coupling of rotational and translational degrees of freedom [4]. We analyze the influence of nonlinear vibrations on the proton velocity, which leads to a solitonic mechanism.

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SPECTROSCOPY OF THE RADIATION-INDUCED PARAMAGNETIC CENTRES IN CRYSTALS AND GLASSES

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A review of our results in studies of the radiation-induced paramagnetic centers in oxide crystals and glasses are presented and analyzed in comparison with available literature data. In particular, the X-band electron paramagnetic resonance (EPR) as well as thermally-stimulated luminescence (TSL) spectra of the UV-, X-, γ-, and β-irradiated crystals and glasses of the $CaO–Ga_2O_3–GeO_2$ system and glasses of the $SiO_2–Na_2O–CaO–P_2O_5$ system (Bioglass®) with different chemical compositions are presented and analyzed.

On the basis of detailed analysis of a the obtained spectroscopic data it was shown that the efficiency of generation of the electron and hole centers in crystals of the $CaO–Ga_2O_3–GeO_2$ system and glasses of the $CaO–Ga_2O_3–GeO_2$ and $SiO_2–Na_2O$-CaO–P_2O_5, systems strongly depends on their basic composition and is almost independent of the type of ionizing radiation and presence of the Fe^{3+} non-controlled impurity and other paramagnetic impurities in the crystal lattice and glass network. The spin Hamiltonian parameters and thermal stability of radiation-induced centers in the investigated crystals and glasses have been determined and analyzed. The EPR spectroscopy data show good correlation with TSL measurements. The electron structure, formation peculiarities and possible models of the local structure of registered radiation-induced paramagnetic centers in crystals as well as glasses of the $CaO–Ga_2O_3–GeO_2$ system and glasses of the $SiO_2–Na_2O–CaO–P_2O_5$ system are considered and discussed.

NON-FINITE DIFFERENCE METHOD FOR ODE AND DDE

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A short review of the properties of the non-finite difference numerical algorithm which has been published recently for ODE (ordinary differential equations) [1, 2] and DDE (delayed differential equations) [3] is discussed. Some of the properties such as being much more accurate than the Verlet algorithm and as fast as the Verlet algorithm makes new perspectives for simulating complex systems. In particular, the use of the algorithm for an effective storing of dynamical data is considered.

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EVERYTHING ABOUT THE STATISTICS OF THE ISING MODEL

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The Zipf-Mandelbrot power law and its connection with the inhomogeneity of the system has been used. We describe the statistical distributions of the domain masses in the Ising model near the phase transition induced by the temperature. For the large domain masses we observe the characteristic irregularities. The statistical distribution near the critical point appears to be of the Pareto type. The hyperbolic functions and Shannon entropy are also considered.

NONUNIFORM ZENO EFFECT

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Zeno effect can be formulated as slowing of the quantum evolution because of frequent observations. We study the Zeno effect in the case when the time intervals between two consequent measurements are different. It can be called a nonuniform Zeno effect. Explicit examples of the nonuniform Zeno effect are presented. We also show that maximal Zeno effect in the case of a large number of measurements can be achieved when the time intervals between consequent measurements are equal.

CORRELATION BETWEEN THE STRUCTURE IN LIQUID AND SOLID STATES OF THE Al–Al_2Cu EUTECTIC ALLOY

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Growth of interest to Al–Cu binary alloys is motivated by opening of new areas of their practical application although these materials have been used for a long time. Besides, Al–Cu binary is the base for synthesizing such comparatively new (1984) materials as quasicrystals. In order to understand the mechanism of processes aimed at the improvement of properties complex studies of structure features including the liquid state are needed.

In this work we present the results of diffraction and molecular dynamic studies of the $Al_{0,83}Cu_{0,17}$ eutectic melt.

The diffraction studies were carried out using a high-temperature diffractometer with a special attachment that allows the investigation of solid and liquid samples at different temperatures up to 1800 K. In our work for MD simulations we have used a nanoMD program developed at the Gdansk University of Technology.

The diffraction study of $Al_{0,83}Cu_{0,17}$ eutectic alloy shows the inhomogeneous atomic distribution in the liquid state at the temperatures close to crystallization point. Molecular dynamic calculations confirm this kind of structure.

The analysis of partial structure factors obtained by means of molecular dynamic shows the significant influence of Al_2Cu-like chemical ordering on atomic distribution in the eutectic melt. It is shown that the Al_2Cu-nanogroups (clusters) are distributed in the Al-matrix.

Using the atomic distribution cell, which was simulated by means of the MD method, we have obtained partial coordination numbers whose interpretation allowed us to make a conclusion about the existence of clusters. The occurrence of such clusters follows directly from the model atomic distribution. By a comparison of these clusters in the liquid state and a coordination of polyhedron of a solid Al_2Cu compound we can confirm the existence of a correlation between the structure in liquid and solid states of the Al-Al_2Cu eutectic alloy.

DEFINING THERMODYNAMIC PARAMETERS FOR TEXTS FROM RANK–FREQUENCY DISTRIBUTIONS

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From the observed analogy between distributions in statistical physics and rank–frequency dependences known for texts the parameters similar to temperature and fugacity are defined. Due to a high fraction of *hapax legomena* (words occuring only once in a given sample) the Bose-distribution is considered to be appropriate for the analysis. Energy levels are identified with word frequencies and the level occupation corresponds to the number of different words with the same frequency. The calculations are made for some texts written in Ukrainian, English, and Guinean Maninka (in the Nko script).

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PARTIALLY SCREENED INNER ACCELERATING REGION OF PULSARS AND ITS OBSERVATIONAL CONSEQUENCES

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We propose a model that explains the observed thermal X-ray emission from the surface of neutron stars (pulsars). Some characteristics of such radiation allow us to get a lot of information about the polar cap region of the pulsars, where the thermal X-ray radiation is believed to be generated. The model requires the existence of a strong and non-dipolar surface magnetic field. We provide a numerical formalism for the modeling of such structures at the stellar surface and calculating the basic parameters that can be fitted to the observational data. We assume that the source of the pulsar activity is associated with the region just above the polar cap where the electric field has a component along the magnetic field lines. The particles (electrons and positrons) are accelerated in both directions: outward and toward the stellar surface. The back-streaming particles heat the surface and provide the necessary energy for a thermal emission. We discuss various possible configurations of the surface magnetic field and demonstrate that the model naturally allows interpretation of observations.

SCALAR FIELD MODELS OF DARK ENERGY WITH THE BAROTROPIC EQUATION OF STATE: PROPERTIES AND OBSERVATIONAL CONSTRAINTS

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Dark energy is treated as a minimally coupled classical or tachyonic scalar field with the generelised linear barotropic equation-of-state (EoS). The 7-year WMAP data on CMB anisotropy, the Union II dataset on Supernovae Ia and SDSS DR7 data on galaxies space distribution along with other cosmological datasets are used for constraining parameters of such dark energy models. The posterior likelihoods are computed using the Monte Carlo Markov Chain technique. It is shown that the current density and EoS dark energy parameters are well-determined while the adiabatic sound speed, playing the role of early EoS parameter, is determined worse. Meanwhile, the obtained results give a possibility to conclude that current data prefer the scalar field models of dark energy with the increasing EoS parameter. Such dark energy recedes its repulsion properties that will result in the future decelerated expansion and recolapse. We note also that cosmological scalar field models with zero adiabatic sound speed as well as Λ-model (adiabatic sound speed equals -1) are not yet excluded by these observational data a sufficiently hight confidence level.

QUANTUM BLACK HOLE WITH GENERALIZED UNCERTAINTY PRINCIPLE

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We consider the black hole applying the Generalized Uncertainty Principle (GUP). We obtain energy eigenvalues for the black hole. We calculate the entropy and Hawking temperature for the black hole.

MAGNETIC PROPERTIES OF THE METALOORGANIC CHAINS WITH NON-COLLINEAR ANISOTROPY AXES

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The magnetic properties of the metaloorganic chain system, also with non-collinear anisotropy axes, can be numerically analysed on the basis of the quantum Heisenberg model [1]. In order to accurately estimate eigenvalues and eigenstates of the Hamiltonian in a wide range of temperature, the density-matrix renormalization-group method (DMRG) have been used [2].

As an example of the homospin Single Chain Magnets [3], the Mn(III)–Mn(III) acetate meso-tetraphenylporphyrin complex [Mn(TPP)O_2PHPh]H_2O is considered [4]. The chain structure is generated by a glide plane resulting in Jahn-Teller elongation axes of the Mn(III) octahedra that alternate along the chain. Therefore the uni-axial magnetic anisotropy D and g factors have been defined as non-diagonal tensors that lead to the complex-number quantum transfer-matrix.

The high accuracy results of our simulations have been fitted to the corresponding experimental magnetic susceptibility and magnetization data. Numerical results of our quantum Heisenberg model simulations yield an improvement with respect to the classical modeling and provide an insight into the importance of quantum effects.

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DIFFRACTION AND QUASICLASSICAL LIMIT OF THE AHARONOV–BOHM EFFECT

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Since the Aharonov–Bohm is a purely quantum effect which is alien to classical physics it becomes evidently more manifest in the limit of long wave lengths of a scattered particle when the wave aspects of matter are exposed to the maximal extent. As the particle wavelength decreases the wave aspects of matter are suppressed in favour of the corpuscular ones and therefore the persistence of the Aharonov–Bohm effect in the short-wavelength limit seems to be hardly possible. However, we show that the Aharonov–Bohm effect persists in the quasiclassical limit owing to the Fraunhofer diffraction. Quantum-mechanical scattering of a nonrelativistic particle by a vortex centred in conical space is considered, and effects of the transverse size of the vortex are taken into account. We show that the Aharonov–Bohm effect in conical space persists in the quasiclassical limit owing to the Fresnel diffraction.

TOPOLOGICAL DEFECTS IN GRAPHENE

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One-layer film of carbon atoms forms graphene which is the first and up to now the only example of a strictly two-dimensional crystal. This crystal is a gapless semiconductor with unique electronic properties owing to the fact that charge carriers in graphene in the long-wavelength approximation are described by the Dirac–Weyl equation with the speed of light substituted by the Fermi velocity. This results in a rather unexpected bridge between condensed matter physics and theory of relativistic quantized fields — spinor quantum electrodynamics. A theory of the vacuum polarization by singular external fields is employed to study the influence of topological defects in graphene on its electronic properties.

A topological defect (disclination) warps a graphitic sheet, rolling it into a nanocone with the deficit angle taking both positive and negative values that are equal to multiples of 60°. We accomplish a comprehensive study of the role of disclinations for carbon nanostructures by considering both flat and curved layers including those with nontrivial topology, and pointing out observable effects of the layer geometry.