THE 4th INTERNATIONAL WORKSHOP "QUANTUM PHYSICS AND COMMUNICATION"

QPC 2007

LIT

Joint Institute for Nuclear Research
Laboratory of Information Technologies

Quantum Physics and Communication (QPC 2007)

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Book of Abstracts

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Workshop objectives

Quantum information processing is a new research area at the borderline of quantum physics and computer science. The main goal of this field is to go beyond classical computing and classical complexity bounds as well as cryptographic communication protocols by making use of quantum mechanical phenomena. Simultaneously, investigation of resources for quantum computation (such as quantum entanglement) enables the understanding of the fundamental properties of quantum mechanics from a different perspective. Recent advances in the realization of qubits and elementary quantum logic gates using ion traps, cavity QED, NMR technologies, quantum optical systems, superconducting devices and solid state nanostructures open new horizons in quantum information processing. Experimental implementation of phenomena such as quantum teleportation, entanglement swapping or quantum cloning, and, obviously, experimental implementation of quantum key distribution have led to a massive exploration of this field by scientists from various disciplines.

The purpose of Workshop is:

1. to provide a compact and comprehensive overview of recent advances in quantum information theory;
2. to focus on physical aspects of generating, storing and transporting quantum information;
3. to explore possible experimental realizations of quantum logic elements such as qubits and quantum gates;
4. to discuss mathematical and computational aspects of quantum information.

Main topics:

- Physics of quantum information processing.
- Experimental quantum computing.
- Models and logic of quantum computation.
- Coherent control of quantum systems.
- Quantum entanglement.
- Decoherence in quantum systems.
- Quantum communication and cryptography.
- Quantum algorithms.

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MULTI-LAYER EVOLUTION SCHEMES FOR THE FINITE-DIMENSIONAL QUANTUM SYSTEMS IN EXTERNAL FIELDS

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The multi-layer operator-difference schemes for solving time-dependent Schroedinger equation based on a factorization of evolution operator till seventh order accuracy by a time step are elaborated.

The corresponding numerical schemes by spatial variables are devised using Galerkin method and a finite element method of high order accuracy.

Convergence and efficiency of the proposed schemes are demonstrated in the case of an exactly solvable model of the two-dimensional oscillator in time-depended external fields.

ADDITIVITY OF ENTANGLEMENT OF FORMATION ANTISYMMETRIC STATES

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Quantum entanglement is the quantum information processing resource. Thus it is of importance to understand how much of entanglement particular quantum states have, and what kinds of laws entanglement and also transformation between entanglement states subject to. Therefore, it is essentially important to use proper measures of entanglement which have nice properties. One of the major candidates of such measures is "entanglement of formation", and whether this measurement is additive or not is an important open problem. Here we have tried to find it for certain states so called "antisymmetric states" for which the additivity are not solved as far, and show the additivity for them.

A *MATHEMATICA* PROGRAM FOR CONSTRUCTING QUANTUM CIRCUITS AND COMPUTING THEIR UNITARY MATRICES

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In the talk we present a Mathematica program that allows a user to specify a quantum circuit, to visualize it, and to construct the unitary matrix defined by the circuit. For circuits composed from the Toffoli and Hadamard gates the package can also output the corresponding multivariate polynomial system over F_2 whose number of solutions in F_2 determines the circuit matrix. Thereby the matrix can also be constructed by applying to the polynomial system the Groebner basis technique based on the corresponding functions built-in Mathematica. For circuits of more general form the matrix is computed by means of the linear algebra tools built-in Mathematica. We illustrate the circuit matrix construction by a number of examples and compare our program with two other.

AN ALGORITHMIC APPROACH TO SOLVING POLYNOMIAL EQUATIONS ASSOCCIATED WITH QUANTUM CIRCUITS

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In this talk we present an algorithm for solving multivariate polynomial systems over F_2 whose variables (unknowns) also belong to F_2. Such systems completely determine quantum circuits built of the Toffoli and Hadamard gates that form a universal gate basis for quantum computation. Our algorithm is a specialization of the involutive algorithm for constructing Groebner bases to the systems indicated. The algorithm has been implemented in C++, and we demonstrate its practical efficiency by some serial benchmarks. The benchmarks are obtained by converting into the form of systems over F_2 of the standard benchmarks widely used for testing and comparison of the Groebner bases software.

QUANTUM FIDELITY OF GAUSSIAN STATES IN OPEN SYSTEMS

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In the framework of the theory of open systems based on quantum dynamical semigroups, we study the quantum fidelity for Gaussian states, which are an important kind of states of continuous-variable systems, intensively applied at present in the field of quantum information processing and communication. For a harmonic oscillator interacting with an environment, in particular with a thermal bath, an initial Gaussian pure state, taken of the form of a correlated squeezed state, remains Gaussian, but it becomes mixed under the influence of the decoherence phenomenon, which takes place during the interaction. We study the dependence of the quantum fidelity of these states on the initial squeezing and correlation parameters, dissipation coefficient and temperature of the bath.

We consider also two independent harmonic oscillators, in an initially separated Gaussian state, and discuss the possibility of entanglement generation during their interaction with the environment. As a result of the competition between entanglement generation and decoherence, we show that the quantum correlations are persistent in time and, for certain types of diffusive and dissipative environments, the asymptotic state is a bipartite entangled equilibrium state.

ENTANGLEMENT PRODUCTION WITH TRAPPED BOSE ATOMS

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A system of traps is considered, each containing a large number of Bose-condensed atoms. This ensemble of traps is subject to the action of an external modulating field generating nonequilibrium nonground-state condensates. When the frequency of the modulating field is in resonance with the transition frequency between two different topological coherent modes, each trap becomes an analog of a finite-level resonant atom. Similarly to the case of atoms in an electromagnetic resonant field, one can create entanglement between atomic traps subject to a common resonant modulating field generating higher coherent modes in each of the traps. A method is suggested for regulating entanglement production in such a system of multitrap and multimode Bose-Einstein condensates coupled through a common resonant modulating field. Several regimes of evolutional entanglement production, regulated by manipulating the external field, are illustrated by numerical calculations.

SYMPLECTIC STRUCTURE OF QUANTUM PHASE AND STOCHASTIC SIMULATION OF QUBITS

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The starting point for such an approach is the projective interpretation of the Hilbert space H as the space of rays. Special stochastic representation of the wave function in quantum mechanics (QM), based on soliton realization of extended particles, is suggested with the aim to model quantum states via classical computer. Entangled solitons construction being introduced in the nonlinear spinor field model, the Einstein-Podolsky-Rosen (EPR) spin correlation is calculated. The concept of stochastic qubits is used for quantum computing modelling.

RESONANCE REFLECTION OF POLARIZED LIGHT

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The resonance reflection of laser radiation having linear polarization is experimentally and theoretically investigated. Some applications of the found features of selective reflection for quantum optics problems and quantum information processing are discussed.

GEOMETRICAL MEASURE OF THE ENTANGLEMENT

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As a measure of entanglement of three-partite pure state the distance between this state and a set of fully disentangled states is considered. This distance can be calculated for W-class three-qubit pure states and generalized GHZ-states in explicit analytical form. Obtained results give the possibility to "visualize" measure of entanglement.

QUANTUM COMPUTING WITH SINGLE-PHOTON PULSES IN DOPED FIBERS

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In our work we investigate the problem of one-photon pulse propagation in photonic-crystal fibers doped by rare-earth atoms. A special interest to these systems is connected with quantum coherent effects and optical interference that take place during absorption and re-emission of light in multi-level atomic systems. These effects are accompanied by a lot of unique physical phenomena. Some of them are: electromagnetically induced transparency when the absorption coefficient is close to zero for the medium excited by external electromagnetic field, and the probe pulse remains unchanged during its propagation; "slow" light formation when group velocity of probe pulse falls down to several meters per second, and formation of huge values of medium nonlinearity [1].

In the paper we develop nonlinear approach to coherent resonant atom-field interaction [2] that gives new possibilities to control amplitude/phase characteristics and quantum fluctuations of light characteristics by means of changing of control field parameters. We have shown that nonlinear cross-interaction of single-photon pulses leads to formation of time-bin entangled photon states in this case that can be used to creation of multi-qubit quantum processor. In particular, we offer for that multi-M-type nonlinear model of optical field interaction with atomic system. We propose necessary conditions and schemes for realization of universal quantum gates by using of time-entangled states of light in doped crystals and special time-of-arrival measurement procedure. We also discuss new algorithms for time-bin coding and error correction procedure based on multi-level schemes of atom-field interaction in doped medium.

1. A.V. Prokhorov, A.P. Alodjants, S.M. Arakelian, JETP Letters, 80,№12, 2004, pp. 739-742.
2. A.V. Prokhorov , N.V. Korolkova, S.M. Arakelian, Russian J. Optics and spectroscopy, 99, №4, 2005, pp.604-610.

RECONSTRUCTION OF QUANTUM WELL POTENTIALS VIA THE INTERTWINING OPERATOR TECHNIQUE

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One of the most important issues of *quantum engineering* is the construction of low-dimensional structures possessing desirable properties. For instance, in different areas of possible applications of the structures containing quantum wells (QW), it is often required need to have a specific kind of the energy spectrum known beforehand. The following problem arises: the spectrum of QW is given; and it is necessary to reconstruct the QW potential which supports this spectrum.

By using the intertwining operator technique we show how to construct the quantum well potential with desired spectrum for the Schroedinger equation with a position-dependent effective mass. The method allows one to construct phase-equivalent potentials, to generate potentials with an additional bound state and with a removal bound state in comparison with the spectrum of an initial potential. These transformations are equivalent to the generalized Darboux transformations for the Schroedinger equation with a nonconstant mass. The technique provides a systematic procedure for generating novel exactly solvable systems.

THE INFORMATION ASPECT OF MEASUREMENT IN PHYSICS TITLE

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It is known that the quantity of information depends on the perception of man. The macro world has been perceived directly but the micro world by devices. Therefore the perception of micro world is no whole. This fact is cause of the Heisenberg Uncertainty Principle. The particles, bodies (objects) are sources of information and the more their number, the more information. By devices this number is small. Therefore in the micro world we receive information less than that in the micro world. Let's examine the case when in both the worlds the uncertainty is the same. In this case the "macro world+ micro world" system is considered. It is impossible to consider micro- and macro worlds separately from each other. If we increase the number of observable objects in the micro world then it affects on the macro world. In particular on macroscopic devices which give us additional information about inside correlation in the quantum system. This correlation takes place in the famous Einstein-Podolsky-Rosen (EPR) paradox. Exactly, the measurement of state of particle 1 which some time interact with the particle 2 in consequence will be tied with state of particle 2 (entangled state). Niels Bohr has explained the entangled state by the certain configuration of devices. Therefore by measuring impulse of one particle it can be predicted the impulse of another particle. One can say this configuration answer a condition of decrease of uncertainty in the micro world. Here it is possible more deep analysis in considering the observer's consciousness which can or can't be included in this system. If the system is the "macroscopic device + micro world" system then the system is opened. In this case the certain configuration of device about which say Bohr result in the decrease of uncertainty in the micro world and therefore we get additional information. If the system is the "macroscopic device + micro world + observer's consciousness" system then the system is close and the uncertainty in the micro worlds becomes equal to the uncertainty in the macro worlds. In short, the micro world is same visible, i.e. same sensually perceived as the macro world. Included in the system, merged with any configuration of devices the consciousness knows all about the micro world. Is it possible such situation for human consciousness? Certainly, no. The consciousness included in system can't be the consciousness of man, because outside system there is a consciousness of another man. This situation reflects the case when Albert Einstein says about sub quantum of the micro world, about its latent parameters.

INDIVIDUAL EVENTS AND MATHEMATICAL FORMALISM OF QUANTUM MECHANICS

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The act of calculation (including quantum) or of communication is individual event.

However, there is no adequate counterpart of individual event in a standard mathematical formalism of quantum mechanics.

I describe a scheme of generalization of the mathematical formalism, in which such adequate counterpart is present.

ИНДИВИДУАЛЬНЫЕ СОБЫТИЯ И МАТЕМАТИЧЕСКИЙ ФОРМАЛИЗМ КВАНТОВОЙ МЕХАНИКИ

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Акт вычисления (в том числе квантового) или передачи информации является индивидуальным событием.

Однако в стандартном математическом аппарате квантовой механики нет адекватного образа индивидуального события.

Я описываю схему обобщения математического аппарата, в которой такой адекватный образ имеется.

QUANTUM ELASTIC RING AND THE TRAVELING SALESMAN PROBLEM

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As is well known, a possibility of solving the NP-complete problems on quantum and classical computer is still questionable. The generalized Church's thesis in the classical computation theory asserts that any analog computer with finite resources can be simulated efficiently by a digital one. Since no similar results have been proved for quantum computers, there is a chance to overcome the difficulty using an analog quantum computer specially designed to solve some well-defined NP-complete problem.

I consider a quantum elastic ring, which can be realized as a mesoscopic antiferromagnetic domain wall, for solving the traveling salesman problem. Here simulated annealing is caused by the natural dissipation processes, and acceleration of lowering to the global energy minimum is ensured by quantum tunneling of the domain wall.

EPR LIGHT BEAMS AND NON-GAUSSIAN QUANTUM DISTRIBUTIONS IN THE TIME DOMAIN

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In this report we investigate Einstein-Podolsky-Rosen (EPR) light beams in the time domain in application to time resolved quantum communication protocols. This investigation includes problems of two-mode quadrature squeezing and intensity-difference squeezing in the pulsed, nonstationary regimes and continues our investigation of time-modulated squeezing and entanglement [1, 2, and 3]. As a proper device generating EPR light beams in a nonstationary regime, a parametric oscillator (OPO) subjected by a periodic sequence of Gaussian laser pulses is considered. Both types of these devices based on type-I and type-II intracavity down-conversion are investigated in above threshold regimes. We demonstrate important operational regimes (depending on the widths and the durations of the pulses and the intervals between them) for which the level of the total squeezing or integrated on the spectral bandwidth squeezing goes below the standard limit established for an ordinary OPO with monochromatic pumping. For characterization of EPR entanglement in the framework of time-dependent quantum tomography, we present results for time evolution of the Wigner functions within the pulsing period. These investigations include results for the reduced one-mode state of nondegenerate OPO and for EPR states which are combined on a half beam splitter. The quantum distributions presented are non-Gaussian that reflects the non-Gaussian nature of time- dependent EPR states.

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1. G. Yu. Kryuchkyan, Laser-like systems for quantum communication, OSA, Young Optician School, 2-7 May, Armenia, Invited Lectures, p.14, (2007).

2. H. H. Adamyan and G. Yu. Kryuchkyan, Time-modulated type-II optical parametric oscillator: quantum dynamics and strong EPR entanglement, Physical Review **A74**, 023811 (2006).

3. G. Yu. Kryuchkyan and H. H. Adamyan, Strong entanglement of bright light beams in controlled quantum systems, NATO series vol. "Decoherence, Entanglement and Information Protection in Complex Quantum Systems", Kluwer Publishers, (2005).

MULTI-MODE SQUEEZING IN MICRO-STRUCTURED MEDIA

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Quasi-phase matched nonlinear materials such as periodically poled nonlinear crystals, photonic crystals or other microstructured nonlinear media are extremely promising for generation of nonclassical states of light, such as squeezed and entangled states and open interesting perspectives for quantum information. In this report we investigate spectral properties and multimode structure of joint states of photon pair and squeezed states produced by pulsed parametric down conversion in superlattice structures of nonlinear and linear materials, particularly, in periodically poled crystals with linear segments. The key to this approach is the idea of manipulating overall group delay mismatches between the various fields in structured materials. We assume a collinear type-I phase-matching configuration and we analyze one-dimensional propagation serving as a model of a waveguide amplifier. We investigate the multimode output of pulsed degenerate parametric down-conversion on the base of the Schmidt mode decomposition of the biphoton spectrum. We also analyze the efficiency of generation of quadrature squeezed light for two kind of superlattices with periodically poled nonlinear crystals in dependence of the group velocity dispersive terms as well as the relative thicknesses of the nonlinear and linear segments.

This work was supported by Grant ANSEF Ref: 666-PS-Opt. and Grant NFSAT/CRDF, YSU "University Centers of Excellence Program".

PULSED PARAMETRIC OSCILLATOR IN A CHAOTIC REGIME

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We investigate semiclassical and quantum properties of periodically pulsed optical parametric oscillator (OPO). This investigation continues our previous analysis presented in Phys. Rev. A74, 023811 (2006), and involves the problem of transition from a regular to chaotic dynamics for type-I OPO. The operational regimes of light-mode generation are investigated including also numerical analysis on the Poincare section. Strange attractors for dissipative chaotic dynamics are visualized and their symmetry properties are studied. Discussions of quantum chaos are performed by the method of quantum trajectories and concerns to calculations of the Wigner functions.

QUANTUM STATE TRANSFER AND QUANTUM NETWORKS

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The application of theory of quantum networks to quantum state transfer — is very active area of research in recent few years. It is related with problem of controlled quantum state transfer along short distance between different units of quantum information systems. For such purposes instead of traditional methods like optical quantum communication may be used alternative approach, *e.g.*, spin chains, arrays of quantum dots, *etc.* The area is situated somewhere on the boundary of theory of quantum computation and quantum communications and now attracts attention of researchers from both these branches of quantum information theory.

An alternative example of "distribution" of quantum state actively developed nowadays — is quantum walk. In this presentation is shown, how application of methods developed for some problems of programmable quantum control with higher dimensional system allows produce very natural description of common properties of quantum walk and state transfer. It is revisited one simple kind of controlled quantum excitation, minimalist example of Benioff's quantum robot, "quantum bot," and recalled, that Hadamard quantum walk may be derived as special case of such excitation with alternating state of control register. At the same time, quantum state transfer is analogue of similar system, but with fixed state of control register and special choice of basis.

In general case quantum control may affect on arbitrary internal states. Quantum bot — is specific example of deterministic programmable quantum controller or quantum gate array, when as basic states are chosen localised states of some distributed quantum system. Due to such property and simple relation of quantum bots both with quantum state transfer along Heisenberg chain and Hadamard quantum walk, both these examples have natural description using theory of programmable quantum gate arrays.

A. Yu. Vlasov, "Universal hybrid quantum processors," *Particles and Nuclei Letters*, 1[116], pp. 60–65 (2003).
A. Yu. Vlasov, "Programmable quantum networks with pure states," in J. E. Stones (ed), *Computer Science and Quantum Computing*, (Nova Science Publishers, Inc., NY 2007), pp. 33–61; *Preprint* quant-ph/0503230.
A. Yu. Vlasov, "Quantum Bots, Quantum Walks and Quantum State Transfer," in preparation.

EPR PARADOX, BELL'S INEQUALITIES AND RELATED EXPERIMENTS

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It is shown that there are no paradox in the EPR paradox, Bell's inequalities are noninformative, and experiments proving violation of Bell's inequalities, prove nothing.

ANTISYMMETRIZATION PROCEDURE OF MANY-PARTICLE STATES

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An efficient procedure for large-scale calculations of the coefficients of fractional parentage (CFPs) for a single-shell with isospin is presented. The approach is based on a simple enumeration scheme for antisymmetric many-particle states and an efficient method for constructing the eigenvectors of an idempotent matrix. We investigate the characteristics of the introduced CFPs basis and the application of this procedure to the harmonic-oscillator shell-model approach. The results of one-particle and two-particle CFPs calculations for large values of quantum angular momenta are presented. The developed computer code for calculation of the CFPs proves to be very quick, efficient, and numerically stable and produces results possessing only small numerical uncertainities.

SYMMETRY ENTANGLEMENT IN POLARIZATION BIPHOTON OPTICS

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Two ways of producing entangled states due to symmetry are discussed in detail within the framework of polarization quantum optics [1,2]. One of them is related to the synergetic role of (boths local and global) SU(2) - symmetries of light polarization states [1,3] and yields kinematic entangled states owing to the introduction of the SU(2) polarization basis in the Fock space and specific biphoton clusters. Another one has a dynamic nature and makes use of SU(2) polarization transformations (of both local and global types) to produce new entangled states from some initial ones. General statements are elucidated by some examples for one - and many - biphoton states. Results obtained can be used to analyze entangled states produced in spontaneous parametric scattering processes in multiply domained KH2PO4 crystals [4,5].

1. V.P. Karassiov. JETP Letters, **84**, 640 (2007).
2. V.P. Karassiov. Opt. Spektrosk., **103**, 143 (2007).
3. V.P. Karassiov. Opt. Spektrosk., **91**, 568 (2001).
4. G.Kh. Kitaeva, S.P. Kulik, A.N. Penin, and A.V. Belinsky. Phys. Rev. **B 51**, 3362 (1995).
5. V.P. Karassiov, S.P. Kulik. JETP, **131**, 30 (2007).

STOKES-ANTI-STOKES ENTANGLEMENT IN STIMULATED RAMAN SCATTERING

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A cavity model of the Raman scattering with an undepleted laser field is considered. An analysis for onset of quantum entanglement between the scattered Stokes and anti-Stokes fields depending on their coupling constants with the pump field and on the state of phonons is performed.

AN APPLICATION OF COMPUTER ALGEBRA SYSTEM CADABRA TO QUANTUM FIELD AND QUANTUM MECHANICS PROBLEMS

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Today there are about 26 computer algebra systems (CAS). Each of these systems can be classified in universal and problem oriented CAS. The feature of general purpose CAS is an ability for decide general problems, for example solution of different equation, manipulation whit famous series, to simplify expression etc. The advantage of problem oriented system CADABRA is the solution of problems encountered in the field theory. It has extensive functionality for tensor polynomial simplification and spinor in quantum mechanics.

In the report we present the review of new CAS CADABRA (http://www.aei.mpg.de/ ~peekas/cadabra/index.html) which applied in solution of problems in the field theory and the problem of quantum mechanics.

СИСТЕМА КОМПЬЮТЕРНОЙ АЛГЕБРЫ CADABRA В ПРИЛОЖЕНИИ К ПОЛЕВЫМ И КВАНТОВО-МЕХАНИЧЕСКИМ ЗАДАЧАМ

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В настоящее время известно около 26 систем компьютерной алгебры. Эти системы можно отнести либо к узкоспециализированным, либо универсальным. Особенностью универсальных систем является способности решать задачи широкого круга, в какой-то мере распространенных задач, например, решение уравнений, упрощение выражений. Преимущество узкоспециализированной системы CADABRA – направленность на решение полевых задач, работа с тензорами и спинорами.

В докладе рассматривается специализированная система CADABRA (http://www.aei.mpg.de/~peekas/cadabra/index.html), применение которой заключается в решении задач теории поля и квантово-механических задач.

AN APPLICATION OF TWO-SPINORS CALCULUS TO QUANTUM FIELD AND QUANTUM MECHANICS PROBLEMS

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Today in quantum field and quantum mechanics problems the four-spinor and quaternion formalism is usually applied. However both these approaches have a number of lacks. Replacement of these formalisms with the formalism of two-spinor is represented more adequate, operations with which have the extremely simple appearance.

In the report advantages of the given approach and its application to quantum mechanics and quantum field problems are considered.

ПРИМЕНЕНИЕ 2-СПИНОРНОГО ИСЧИСЛЕНИЯ К КВАНТОВОМЕХАНИЧЕСКИМ И ПОЛЕВЫМ ЗАДАЧАМ

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В квантовомеханических и полевых задачах обычно применяется формализм дираковских 4-спиноров или кватернионов. Однако оба этих подхода имеют ряд недостатков. Представляется более адекватным замена этих аппаратов аппаратом лоренцовых 2-спиноров, операции с которыми имеют крайне простой вид.

В докладе рассматриваются преимущества данного подхода и его применение к квантовомеханическим и квантовополевым задачам.

CORRELATIONS OF POLARIZATIONS AND ENTANGLED STATES IN THE TWO-PHOTON SYSTEM

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Correlations of the linear and circular polarizations of two photons have been theoretically investigated. The structure of the polarization density matrix of two photons is discussed. The polarization of a two-photon state is described by the one-photon Stokes parameters and by the components of the correlation "tensor" in the Stokes space. It is shown that for the two-photon decays $\pi^0 \to 2\gamma$, $\eta \to 2\gamma$, $K_L^0 \to 2\gamma$, $K_S^0 \to 2\gamma$ and the cascade process $|0\rangle \to |1\rangle + \gamma \to |0\rangle + 2\gamma$ ($|0\rangle$ and $|1\rangle$ are states with the spin 0 and 1, respectively) the final two-photon state represents a characteristic example of the entangled (nonfactorizable) state, and in the case of these decays the correlations between the Stokes parameters have the purely quantum character: the incoherence inequalities of the Bell type for the components of the correlation "tensor", established previously for the case of classical mixtures, are violated. The general analysis of the registration procedure for the system of two correlated photons by two one-photon detectors is performed.

MODELLING OF RADIATION TRANSITIONS OF QUANTUM OBJECTS WITH ONE OPTICAL ELECTRON

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Quantum mechanics with the non-negative quantum distribution function is a mathematical model of quantum objects with nonzero size and nontrivial structure. The corresponding quantization rule is non contradictory and the quantum model of the Kepler problem adjusted to spectrum of optical electron describes spectral characteristics of alkali atoms and other quantum objects with one optical electron. Considered model is uniform for radiation transitions in free space and in presence of a magnetic field.

МОДЕЛИРОВАНИЕ РАДИАЦИОННЫХ ПЕРЕХОДОВ КВАНТОВЫХ ОБЪЕКТОВ С ОДНИМ ОПТИЧЕСКИМ ЭЛЕКТРОНОМ

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Квантовая механика с неотрицательной квантовой функцией распределения является математической моделью квантовых объектов с ненулевыми размерами и нетривиальной структурой. Соответствующее правило квантования является непротиворечивым, а квантовая модель задачи Кеплера, адаптированная по спектру оптического электрона, описывает спектральные характеристики атомов щелочных металлов и других квантовых объектов с одним оптическим электроном. Рассматриваемая модель единообразна для радиационных переходов в свободном пространстве и в присутствие внешнего магнитного поля.

LOCAL CLONING OF ENTANGLED QUBITS

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We discuss the exact cloning of orthogonal but entangled qubits under local operations and classical communication. The amount of entanglement necessary in blank copy is obtained for various cases. Surprisingly this amount is more than 1 ebit for certain set of two nonmaximal but equally entangled states of two qubits system. To clone any three two qubits Bell states at least $\log_2 3$ ebit is necessary.

THERMAL PAIRWISE ENTANGLEMENT IN AN INHOMOGENEOUS MAGNETIC FIELD

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Recently, we have investigated the entanglement of spin pairs in alternating open spin chains in the equilibrium state. The results demonstrate the dependence of the entanglement on the temperature, chain's length, the positions of the spins, and the ratio of the spin-spin coupling constants. We have shown that numerical characteristics of the entanglement are oscillating functions of the position of the spin pair in the chain and explain an influence of the chain ends on the entanglement. Here we investigate pairwise entanglement in an open alternating spin-1/2 chain with the XY-Hamiltonian in the equilibrium state in an inhomogeneous magnetic field. The boundary effects decay in the high homogeneous external magnetic field. We show that the entanglement is conserved in very strong inhomogeneous external magnetic fields at a finite temperature. We demonstrate that open alternating spin chains with the XY-Hamiltonians in an inhomogeneous magnetic field can be used for the solution of the qubit addressing problem.

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THE PAIRWISE ENTANGLEMENT IN NMR EXPERIMENTS

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It is well known that pseudo-pure states, obtained with liquid state NMR, are not entangled. We consider a molecular crystal with two dipolar coupled nuclear spins (s=1/2) in crystalline cell in a strong external magnetic field. The entanglement of the quasi-equilibrium state of the system, which is irradiated by the resonance rf-field, in the rotating reference frame is investigated with the Wootters criterion. The temperature at which an entangled state appears is in the microkelvin range. We also studied entanglement in an open alternating chain of nuclear spins with the XY-Hamiltonian in an external magnetic field under thermodynamic equilibrium conditions. The developed approach is based on an original method of diagonalization of the XY-Hamiltonian of open alternating spin chains. We show that numerical characteristics of the entanglement are oscillating functions of the position of the spin pair in the chain and explain an influence of the chain ends on the entanglement. The obtained results allow us to conclude that open inhomogeneous spin chains can be used as a quantum register in quantum computers.

This work was supported by Russian Foundation for Basic Research (project no. 07-07-00048).

DECOHERENCE OF ONE-DIMENSIONAL SYSTEMS OF DIPOLAR COUPLED SPINS IN MULTIPLE-QUANTUM NMR EXPERIMENTS IN SOLIDS

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We have investigated decoherence of dipolar coupled one-dimensional systems in multiple-quantum (MQ) NMR experiments. MQ NMR experiments consist of four different periods: preparation, evolution, mixing and detection. MQ NMR coherences are created during the preparation period. The exact solution yields MQ coherences of zeroth and second orders only in the approximation of nearest neighbor interactions at the end of the preparation period. The decoherence process occurs during the evolution period due to the dipole-dipole interactions (DDI). We have developed a theory of magnetization decay in the evolution period taking into account the zz-part of the DDI only. The theory is based on the fermionic approach to MQ NMR dynamics which was developed in Ref. [1]. The theory shows that the magnetization decay obeys the Gaussian law in accordance with the experimental data [2] and the phenomenological theory [3]. We have performed supercomputer analysis of dynamics and decoherence in one-dimensional chains containing up to fifteen spins. The numerical calculations take into account the DDI of remote spins. We compared our theoretical and numerical results with experimental data [2] and have found that clusters consisting of 5-7 spins are formed in MQ NMR experiments on fluorine chains in calcium fluorapatite at the duration of the preparation periods 480 ms and 1200 ms. The obtained results shed light on some problems of decoherence of dipolar coupled clusters and its dependence on the number of the spins.

The work is supported by the Russian Foundation for Basic Research (project no.07-07-00048).

[1] S.I.Doronin, I.I. Maksimov, E.B. Feldman, ZETF 118, No. 3, 687-700 (2000).
[2] Cho, P.Cappellaro, D.G. Cory, C.Ramanathan, Phys. Rev. B 74, 224434 (2006).
[3] A.Fedorov, L. Fedichkin, J. Physics: CondensedMatter 18, 3217-3228 (2006).

REMARKS ON BELL INEQUALITIES

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We simplify slightly Pitowsky's mathematical structure for deriving bell inequalities, and point out the connections to Tsirelson's bound. EPR paradox and hidden variable models are discussed briefly.

S-MATRIX, MONODROMY AND SET OF UNIVERSAL GATES

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It is known, that it is possible to construct the set of universal gates by monodromy matrices of logarithmic connections on holomorphic vector bundles. Such a approach corresponds to holonomies of connections in the holonomic quantum computing, but holonomies do not depend on the path of integration. Unlike the monodromy matrices the scattering matrices are encountered in physical experiments, moreover there exists a one-to-one correspondence between the monodromy and scattering matrices in the one-dimensional case. We describe potentials and the corresponding S-matrices which generate the set of universal gates.

HALTING AND UNIVERSALITY FOR QUANTUM TURING MACHINES - A CRITICAL REFLECTION

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Manin, Feyman and Deutsch have viewed quantum computing as a kind of universal physical simulation procedure. Much of the writing about quantum logic circuits and quantum Turing machines has shown how these machines can simulate an arbitrary unitary transformation on a finite number of qubits. The problem of universality has been addressed most famously in a paper by Deutsch, and later by Bernstein and Vazirani as well as Kitaev and Solovay. The quantum logic circuit model, developed by Feynman and Deutsch, has been more prominent in the research literature than Deutsch's quantum Turing machines. Quantum Turing machines form a class closely related to deterministic and probabilistic Turing machines and one might hope to find a universal machine in this class. A universal machine is the basis of a notion of programmability. The extent to which universality has in fact been established by the pioneers in the field is examined and this key notion in theoretical computer science is scrutinised in quantum computing by distinguishing various connotations and concomitant results and problems. In particular, we also consider the halting scheme for quantum Turing machines. The scheme originally proposed by Deutsch appears to be correct, but not exactly as originally intended. In this regard, we discuss the result of Ozawa as well as the objections raised by Myers, Kieu and Danos and others.

TWO INTERACTING SPINS IN EXTERNAL FIELD AND ITS APPLICATION TO QUANTUM COMPUTATION

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We consider the so-called two-spin equation that describes four-level quantum systems. Recently, these systems attract attention due to their relation to the problem of quantum computation. We study general properties of the two-spin equation and show that the problem for certain external backgrounds can be identified with the problem of one spin in an appropriate background. This allows one to generate a number of exact solutions for two-spin equations on the basis of already known exact solutions of the one-spin equation. Then we discus possible applications of these results to quantum computation.

ENTANGLEMENT CRITERIA FOR CUMMINGS - TAVIS MODEL WITH TWO ATOMS IN NONIDEAL CAVITY

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The dynamics of two identical two-level atoms in non-ideal cavity it is considered. Using approach developed before by us for the case of one two-level atom, the analytical expression for density matrix of the system is presented. Dynamics of level populations and the mean number of photons and correlation function for photons are calculated. Essential dependencies on initial field state, damping constant and atomic distance have been observed. Using the Peres - Horodecki and Wootters criteria exact expression for entanglement dynamics of two identical two-level atoms in cavity is given. Influence of detuning and damping constants are investigated. We have found that time dependencies of the Peres - Horodecki and Wootters parameters are very similar.

POSSIBLE IMPLEMENTATIONS OF CNOT AND CCNOT GATES

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An implementation of CNOT gate based on coupled double quantum dots is suggested. The qubit state is determined by the position of non-paired electron in non-symmetric double quantum well. Another optical implementation is suggested for CCNOT gate. It is based on M-scheme of level transitions. Theoretical description of the gate is given.

QUANTUM INFORMATION TRANSMISSION BETWEEN TWO QUBITS THROUGH AN INTERMEDIARY PHOTON GAS

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The theory of the quantum information transmission between two semiconductor two-level quantum dots as two qubits through an intermediary photon gas in a cavity is presented. The reduced density matrix of each two-level quantum dot is the quantum information encoded into this qubit. The quantum information exchange between two distant qubits embedded in the photon gas is performed in the form of the mutual dependence of their reduced density matrices due to the interaction between the electrons in the qubits and the photon gas. The system of rate equations for the reduced density matrix of the two-qubit system is derived. From the solution of this system of equations it follows the mutual dependence of the reduced density matrices of two distant qubits.

GEOMETRIZATION OF QUANTUM PHYSICS

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It is shown that the Dirac equation for free particles and the Maxwell equations for free electromagnetic waves can be considered as a description of specific propagating distortions of the space euclidean geometry (space topological defects). This approach is based on possibility of interpretation of the wave functions as vectors realizing representation of the fundamental group of the closed topological space-time 4-manifold. Mass, spin and thr light velocity appear to be topological invariants. Such a concept explains all so called "strange" properties of quantum formalism: probabilities, wave-particle duality, nonlocal instantaneous correlation between noninteracting particles (EPR-paradox) and so on. The Dirac equation for a hydrogen atom can be also interpreted as the relation describing the space topological defect. Electromagnetic potentials play here the role of connectivities of the defect universal covering space, and gauge invariance of the electromagnetic field reflects the symmetry of the above noneuclidean space (the Weil space). Preliminary results: 2007, J.Phys.,Conf.Ser., 67, 012037 (arXiv 0706.346).

ГЕОМЕТРИЗАЦИЯ КВАНТОВОЙ ФИЗИКИ

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В рамках единого геометрического подхода показано, что уравнение Дирака для свободного материального поля и уравнения Максвелла для свободных электромагнитных волн можно рассматривать как описание распространяющихся искажений эвклидовой геометрии пространства (пространственных топологических дефектов). Подход основан на возможности

интерпретации волновых функций как векторов, реализующих представление фундаментальной группы замкнутого топологического пространственно-временного 4-многообразия. Масса, спин и скорость света являются топологическими инвариантами многообразия. Находят объяснение все «странные» особенности квантового формализма: появление вероятностей, корпускулярно-волновой дуализм, нелокальная мгновенная корреляция между состояниями невзаимодействующих частиц (ЭПР-парадокс) и т.д. Уравнение Дирака для атома водорода можно также проинтерпретировать как описание топологического дефекта. При этом электромагнитные потенциалы играют роль коэффициентов связности накрывающего пространства дефекта, а калибровочная инвариантность электромагнитного поля отражает симметрию указанного, неэвклидового пространства (пространства Вейля). Предварительные результаты: 2007, J.Phys.,Conf.Ser., 67, 012037 (arXiv 0706.346).

DISCRETE SYMMETRY ANALYSIS OF LATTICE SYSTEMS

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We consider discrete dynamical systems and lattice models in statistical mechanics from the point of view of their symmetry groups. We describe a C program for symmetry analysis of discrete systems. Among other features, the program constructs and investigates *phase portraits* of discrete dynamical systems *modulo groups* of their symmetries, searches dynamical systems possessing specific properties, e.g., *reversibility*, computes microcanonical *partition functions* and searches *phase transitions* in mesoscopic systems. Some computational results and observations are presented. In particular, we explain formation of moving soliton-like structures similar to "*spaceships*" in cellular automata.

ENTANGLEMENT IN TWO-PHOTON TAVIS-CUMMINGS MODEL INDUCED BY THERMAL NOISE

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The atom-atom entanglement for one-photon and two-photon Tavis-Cummings model with a different type of transitions between atomic levels has been considered. The negativity of two atomic qubits for different initial pure and mixed atomic states has been calculated. The possibility of atomic entanglement induced by thermal noise has been established.

BUILDING OF THE QUANTUM CRYPTOGRAPHY PROTOCOL USING NO-CLONING THEOREM

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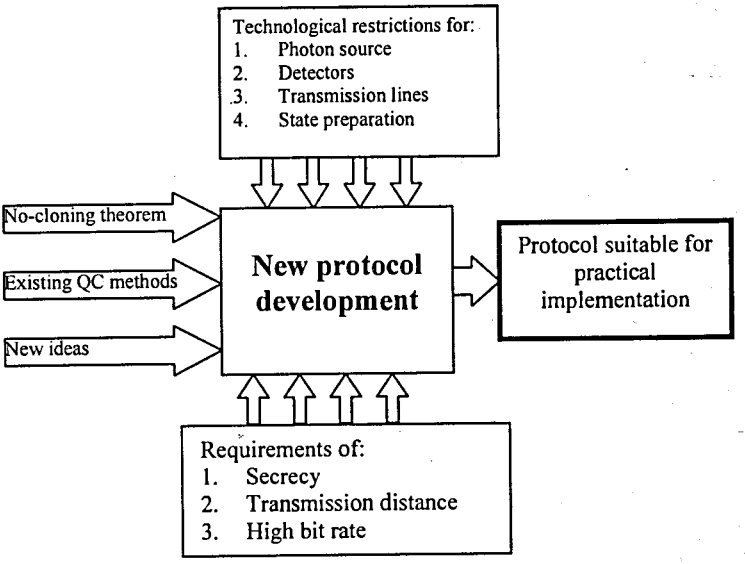
The main aim of the quantum cryptography protocol is the maximal secrecy under the conditions of the real experiment. This work presents the result of the new protocol building with the use of the secrecy maximization. While using some well known approaches this method has allowed to achieve the completely new results in quantum cryptography.

The aim of quantum cryptography is the establishing proofed secure communication between two parties (Alice and Bob) [1, 2]. The first QC protocol is BB84 [1] up to now it is the most popular and convenient for experimental applications. Its secrecy has been proved mathematically [3]. What else is need in quantum cryptography? The point is that with the use of current technologies the BB84 protocol has restriction in the transmission speed and distance. So the aim of practical quantum cryptography is to achieve not only secrecy but also high bit rate and longer distance. Moreover the quantum cryptography protocol should pass the scope of the present technologies.

Quantum cryptography secrecy is based on the no-cloning theorem. In what case will



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