O1. Rydberg Excitations in BECs and Cold Clouds

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Cold Rydberg atoms have been the subject of intense study and have found applications in diverse areas of quantum physics. Interactions between neutral ground state atoms are weak compared to those of atoms excited to Rydberg states. This is due to the large electric dipole moments of Rydberg atoms which lead to long-range, dipole-dipole interactions. One result of these interactions is the dipole blockade effect, in which strongly interacting atoms excited by the same driving pulse may prevent the excitation of neighbouring atoms. This blockade offers several applications, for example the realization of quantum logic gates [1]. Recent results with two trapped atoms show the possibility of creating entangled states [2].

By investigating the dipole blockade effect in larger atomic samples, it is possible to study collective phenomena. To this end, we produce Bose Einstein Condensates (BECs) in different density regimes in which Rydberg atoms are created and then ionised. Our results for condensates expanded to different sizes in the one-dimensional trap agree well with the intuitive picture of a chain of Rydberg excitations [3].

Furthermore, to add spatial order to this system, we initialise ultra-cold atoms in optical lattices. In such configurations the Rydberg excitations in the optical lattice do not destroy the phase coherence of the condensate. Our results in that system agree with the picture of localized collective Rydberg excitations including nearest-neighbour blockade.

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O2. Selective Addressing of Amplification of Narrow Resonance Formed in Transmission Spectrum of Nano-cell Placed in External Magnetic Field

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It was demonstrated in [1,2] that the use of nano-metric-thin cell (NTC) filled with Rb atomic vapor and having the thickness of $L = \lambda$ (where $\lambda = 794$ nm is the wavelength of laser radiation whose frequency is resonant to the atomic transition of the D_1 line of Rb) allows one to narrow velocity selective optical pumping (VSOP) resonances in the transmission spectrum. The VSOP resonance allows one to separate and study the atomic transitions between the Zeeman levels of the hyperfine structure (optical domain) of the D_1 line of the ^{87}Rb atoms in magnetic fields with $\boldsymbol{B}$ from 10 to 5000 G. As a rule ten–fifteen VSOP resonances are formed.

However, in some cases the amplitude of a VSOP resonance could be small enough, thus there is a need to increase the VSOP amplitude. We propose a scheme, where an additional laser radiation is used with appropriate frequency and which allows of selective addressing of amplification of narrow resonance formed in transmission spectrum of nano-cell placed in an external magnetic field.

Particularly, in case of using a probe radiation with σ^- polarization, the VSOP resonances formed on ^{87}Rb, D_1 line, $F_g = 1 \rightarrow F_e = 2$ atomic transitions have a small amplitude decreasing with the magnetic field strength $\boldsymbol{B}$. By applying a second laser radiation (coupling) with σ^+ polarization (in this case a V-system is formed) the selective addressing of VSOP amplification becomes possible. Note, that the probability of $F_g = 1 \rightarrow F_e = 2$atomic transitions with σ^+ polarization excitation (in contrary to σ^- polarization excitation) increases with magnetic field strength $\boldsymbol{B}$.

Theoretical model presented well describes the experimental results.

Research conducted in the scope of the International Associated Laboratory IRMAS.

[1] D. Sarkisyan, A. Papoyan, "Optical processes in micro- and nanometric thin cells containing atomic vapor", (Horizons in World Physics, vol.263), Ed.: R. Drampyan, Nova Science Publishers, ISBN: 978-1-60741-025-6, Ch.3, pp.85-124 (2009).

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O3. Nonlinear Magneto-optical Resonances for Systems with J ~100 Observed in K_2 Molecules

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I will present the results of an experimental as well as theoretical study of nonlinear magneto-optical resonances in diatomic potassium molecules in the electronic ground state with large values of the angular momentum quantum number J ~100. At zero magnetic field, the absorption transitions are suppressed because of population trapping in the ground state due to Zeeman coherences between magnetic sublevels of this state along with depopulation pumping. The destruction of such coherences in an external magnetic field was used to study the resonances in this work. K_2 molecules were formed in a glass cell filled with potassium metal at a temperature above 150°C. The cell was placed in an oven and was located in a homogeneous magnetic field B, which was scanned from zero to 0.7 T. Q-type and R-type transitions were excited with a tunable, single-mode diode laser at a wavelength of 661 nm. Well pronounced nonlinear Hanle effect signals were observed in the intensities of the linearly polarized components of the laser-induced fluorescence (LIF) detected in the direction parallel to the B-field with polarization vectors parallel (I_{par}) and perpendicular (I_{per}) to the polarization vector of the exciting laser radiation, which was orthogonal to **B**. The intensities of the LIF components were detected for different experimental parameters, such as laser power density and vapor temperature, in order to compare them with numerical simulations that were based on the optical Bloch equations for the density matrix. We report good agreement of our measurements with numerical simulations. Narrow, subnatural line width dark resonances in $I_{per}(B)$ were detected and explained.

O4. Power Dependent Van Der Waals Interaction in Cold Atom Reflection

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The role of Casimir forces in the fabrication and performance of micro- and nano-devices has motivated renewed interest on the realization of more precise experiments on ultracold atom reflection by evanescent wave (EW) mirrors [1], than those originally performed in the earlier days of the BEC [2]. The recent results confirm a discrepancy between the measured dependence of the barrier height on the EW power and theoretical predictions obtained from a non-retarded van der Waals-like potential, a retarded potential and the full QED potential [1]. This discrepancy increases with the EW power. In these experiments the reflection potential is considered to be the sum of the optical potential and the Casimir (atom-wall) interaction potential. However, the Casimir force was originally evaluated for ground-state atoms immersed in the electromagnetic vacuum. The only quantum states of the field involved in the calculation where the vacuum state and virtual one-photon states. We show that a calculation of the van der Waals potential for an atom in the presence of an EW leads to a power-dependent potential [3], which yields the linear behavior observed experimentally for the barrier height as a function of the EW power.

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O5. Метод электронного парамагнитного резонанса при исследовании материалов для квантовой электроники (YAG, YLuAG, YAP, YLuAP, $PbGa_2S_4$)

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В работе приведены результаты исследования методом электронного парамагнитного резонанса (ЭПР) лазерных материалов и сцинтилляторов: монокристаллов гранатов $Y_3Al_5O_{12}:Dy^{3+}$, $Y_3Al_5O_{12}:Er^{3+}$, смешанных гранатов $(Y_{1-x}Lu_x)_3Al_5O_{12}:Er^{3+}$, ортоалюминатов иттрия $YAlO_3$: Er^{3+}, Tm^{3+}, Nd^{3+} и Ce^{3+}, смешанных иттрий лютециевых ортоалюминатов $Y_{(1-x)}Lu_xAlO_3$ с примесью ионов Ce^{3+} и тиогаллата свинца $PbGa_2S_4$, активированных редкоземельными элементами Dy^{3+}, Nd^{3+} и Ce^{3+}. Методом ЭПР ионы Er^{3+}, Tm^{3+}, Nd^{3+} и Ce^{3+} в ортоалюминатах обнаружены и исследованы впервые. Впервые обнаружены и исследованы также ионы Dy^{3+}, Nd^{3+} и Ce^{3+} в монокристаллах тиогаллата свинца. Найдены главные значения *g*–тензора и константы сверхтонкого взаимодействия для нечётных изотопов для Dy^{3+}, Nd^{3+}, Er^{3+}, Tm^{3+} в исследованных соединениях. В сложных композиционно-неупорядоченных соединениях YLuAG и YLuAP обнаружен ряд новых, по сравнению с YAG и YAP, парамагнитных центров Er^{3+} и Ce^{3+}, обусловленных изменением симметрии и величины кристаллического поля при изоморфных замещениях Y^{3+} на Lu^{3+} в иттриевой подрешётке этих материалов. Установлена природа и рассчитаны вероятности образования новых парамагнитных центров, приводящих к уширению спектральных линий. Проанализированы возможные механизмы зарядовой компенсации при гетеровалентных замещениях Pb^{2+} на $РЗ^{3+}$ в монокристаллах тиогаллата свинца.

O6. Generation of Mesoscopic Entangled States in a Cavity Coupled to an Atomic Ensemble

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In my talk I will discuss the interaction of two quantized cavity modes and a classical pump field with an atomic ensemble of six level atoms. I will show that due to the quantum interference the Raman emission of the photons in our system is quantum state selective. The photons in our scheme can be emitted in either mode of the system but simultaneous creation of the photons in both modes is forbidden. This unitary process leads to a superposition state generation with mesoscopic number of photons either in one or another mode. We also propose an efficient method to produce photonic or atomic NOON states.

O7. Nonlinear Quantum Reflection of a Bose-condensate by a Step Potential

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We analyze the matter wave transmission across a step potential within the cubic-nonlinear Schrödinger equation. We present a comprehensive analysis of the corresponding stationary problem based on an exact second order nonlinear differential equation for the probability density. The exact solution of the problem in terms of the Jacobi elliptic *sn*-function is presented and analyzed. Qualitatively distinct types of wave propagation picture known before are classified depending on the input parameters of the system. Analyzing the 2D-space of involved dimensionless parameters, the nonlinearity and the reflecting potential's height/depth given in the units of the chemical potential, we show that the region of the parameters that does not support finite solutions is given by an advanced closed curve defined by a parabola and two lines. We show that this results from a specific singular point induced by the nonlinearity. In the parameter space, this singular point plays a role of a bifurcation point that causes a jump from one evolution scenario to another possible one. The position of this point as well as the solutions of the problem for all the relevant regions of the involved parameters are explicitly determined and the peculiarities of the evolution scenarios (oscillatory, non-oscillatory, diverging) are described and analyzed in detail.

O8. Quantum Repeaters based on Deterministic Storage of a Single Photon in distant Atomic Ensembles

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Quantum repeaters hold the promise to prevent the photon losses in communication channels. Most recently, the serious efforts have been applied to achieve scalable distribution of entanglement over long distances. However, the probabilistic nature of entanglement generation and realistic quantum memory storage times make the implementation of quantum repeaters an outstanding experimental challenge. We propose a quantum repeater protocol based on the deterministic storage of a single photon in atomic ensembles confined in distant high-finesse cavities and show that this system is capable of distributing the entanglement over long distances with much higher rate as compared to previous protocols, thereby alleviating the limitations on the quantum memory lifetime by several orders of magnitude. Our scheme is robust with respect to phase fluctuations in quantum channel, while the fidelity imperfection is fixed and negligibly small at each step of entanglement swapping.

O9. Quantum Logical Gate SWAP in Three- and Four- Level Cold Atomic Ensemble

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The building blocks for realization of quantum information processing are quantum logical gates. We propose a new method for implementation of quantum SWAP gate, which swaps two initial qubits. The parametric interaction between two qubits at different frequencies is created by classical laser field with constant intensity in three-level cold atomic media. This latter laser field provides electromagnetically induced transparency conditions so that quantum fields propagate with small group velocities and are not absorbed in the medium. We consider also the case of four-level atom, where qubits travel in the medium with equal group velocities and the fidelity of the SWAP gate reaches 100%.

O10. Electromagnetically Induced Transparency Involving D_2 Line of Cs Atoms Confined in Micrometer Thin Vapor Layer

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The effect of electromagnetically induced transparency (EIT) in a Λ-system formed by Cs atoms (6S -6P -6S) contained in extremely thin cells (ETC) (atomic column thickness vary in the range of 0.8–3 μm) was studied both experimentally and theoretically (for the first time). It was found that parameters of the EIT resonance degrade slowly in the case where the frequency of the coupling laser is in resonance with the D_2 transition of Cs.

The specific features of EIT in ETC reveal themselves when the coupling laser has a frequency detuning Δ from the atomic transition. In this case, the width of the EIT resonance rapidly increases upon an increase in Δ at fixed L (an opposite effect takes place in centimeter-scale cells). The strong broadening of the EIT resonance for large values of detuning Δ is caused by the influence of atomic collisions with cell windows on dephasing rate of coherence.

A theoretical model taking into account the peculiarities of transmission spectra when $L = n\cdot$lambda and $L = (2n + 1)\cdot$lambda/2 (n is an integer) has been implemented (where lambda is the laser radiation wavelength 852 nm which is resonant with the Cs D_2 line). The experimental transmission spectra are well described by the developed theoretical model.

Although the main characteristic of the EIT in the Cs vapor and Rb vapor [1–3] are similar, however there are some differences. Particularly, the EIT in the Cs vapor at the same thickness L is somewhat narrower (by 20%) than that in the Rb vapor. This could be caused by smaller Doppler width in the case of Cs vapor.

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O11. Study of Forbidden Atomic Transitions on *D* Line Using Rb Nano-cell Placed in External Magnetic Field

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Our theoretical calculations predict that for magnetic field $B > 300$ G there is expected a strong increase of the probability of the following "forbidden" atomic transitions for π- laser radiation polarization with configuration ($B \,||\, E$), where E is the electric field of the radiation polarization and B is the magnetic field.

i) ^{87}Rb, D_1 line, $F_g = 1$, $m_F = 0 \rightarrow F_e = 1$, $m_F = 0$ (this is "forbidden" transition when $B = 0$)
ii) ^{87}Rb, D_2 line $F_g = 1$, $m_F = 0 \rightarrow F_e = 1$, $m_F = 0$ and $F_g = 2$, $m_F = 0 \rightarrow F_e = 2$, $m_F = 0$ (these are two "forbidden" transitions when $B = 0$)
iii) ^{87}Rb, D_2 line $F_g = 1 \rightarrow F_e = 3$ (here we have three "forbidden" transitions when $B = 0$).

We have implemented the so-called λ-Zeeman technique (LZT) and half-lambda Zeeman technique (HLZT) [1,2] to reveal for the first time both experimentally and theoretically **a strong modification of the above mentioned atomic transitions probabilities and the frequency shift** in an external magnetic field $B > 300$ G. For these studies we used nano-cell filled with Rb.

Obtained experimental results are well described by the developed theoretical model.

Research conducted in the scope of the International Associated Laboratory IRMAS.

[1] D. Sarkisyan, A. Papoyan, "Optical processes in micro- and nanometric thin cells containing atomic vapor", (Horizons in World Physics, vol.263), Ed.: R. Drampyan, Nova Science Publishers, ISBN: 978-1-60741-025-6, Ch.3, pp.85-124 (2009).
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O12. Distinguishing Characteristics of Optical Cooling Effect on Doped Ferroelectrics

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Проблема лазерного охлаждения твёрдых тел, основанная на осуществлении режима анти-Стоксовой люминесценции, представляет в последние годы повышенный интерес не только в связи с чисто научными интересами в области спектроскопии, лазерной физики и теплофизики примесных твёрдых сред, а также благодаря достигнутым практически важным результатами в направлении создания оптических холодильников, лишённых всяких подвижных частей и вибраций, охлаждающих жидкостей и газов, электрических наводок и т.п. Основные усилия исследователей во всем мире сосредоточены на исследованиях легированных редкоземельными ионами низкофононных кристаллов и стёкол, так как они позволяют достичь рекордно низкие для твердотельных рефрижераторов температуры (ниже 100 К).

В настоящей работе на основе детальных спектроскопических исследований кристалла $LiNbO_3:Yb^{3+}$ оценена его перспективность для вышеуказанных применений. Зарегистрированные спектры поляризованного поглощения и люминесценции позволили осуществить на этом материале при комнатных температурах режим анти-Стоксовой люминесценции вблизи 980 нм при оптическом возбуждении на длине волны 1064 нм. Эти исследования показали, что для реализации эффекта оптического охлаждения наиболее выгодно использовать поляризацию возбуждающего излучения, параллельную оптической оси кристалла (π-поляризация). Определена спектральная зависимость эффективности оптического охлаждения исследуемого кристалла от длины волны лазерного возбуждения, оценена минимально достижимая температура охлаждения. Отмечено, что хотя и оксидная матрица исследуемого кристалла не принадлежит к ряду низкофононных твёрдых тел и на ней невозможно получение рекордно низких температур, однако она представляет определённый интерес для реализации твердотельных рефрижераторов, работающих в области температур от комнатных до порядка −50°C, так как здесь кристалл $LiNbO_3:Yb^{3+}$ будет иметь более высокую эффективностью, чем низкофононные фторидные или хлоридные легированные среды. Кроме этого, сегнетоэлектрические свойства матрицы позволят вместо громоздких и сложных оптических методов измерения температуры использовать присущий им пироэлектрический эффект для её оперативного контроля.

O13. Time-resolved Luminescence Spectroscopy of YAG:Er^{3+}–Ce^{3+} Crystal

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В связи с практически важными применениями лазерного излучения вблизи длины волны 1.5 мкм, проблема повышения эффективности работы соответствующих активных сред представляет несомненный интерес. Одним из перспективных методов улучшения выходных характеристик активированных кристаллов является использование эффекта сенсибилизации рабочих примесей соответствующими донорными ионами с целью повышения использования энергии оптического возбуждения в конкретной матрице. Таким удачным сенсибилизатором для рабочих ионов Er^{3+} в матрице YAG-а являются ионы Ce^{3+}, которые благодаря дипольно-разрешённым межконфигурационным переходам между своими энергетическими уровнями, проявляют интенсивные полосы поглощения и эффективные каналы передачи энергии оптического возбуждения рабочим ионам. Это приводит к существенному повышению эффективности использования энергии оптического возбуждения вблизи длины волны 460 нм для реализации генерации вблизи длины волны 1.55 мкм на кристалле YAG:Er^{3+}–Ce^{3+}.

Наши предыдущие исследования касались особенностей и влияния примесных ионов Ce^{3+} на спектральные характеристики люминесценции ионов Er^{3+} в кристалле YAG:Er^{3+}–Ce^{3+}. В настоящей работе приведены результаты исследований кинетических характеристик люминесцентных откликов на короткие оптические импульсы, соответствующие возбуждению различных ионов в примесной подсистеме этого материала. Исследовались времена возгорания, распада и временная задержка пика люминесценции относительно момента выключения возбуждающего импульса, изучалась форма фронта возгорания и распада этих сигналов. В качестве источников возбуждения использовались излучения импульсных лазеров на длинах волн 446, 457, 532, 808 и 980 нм.

Сравнение полученных экспериментальных результатов с теоретическими оценками, полученными на основе численных решений системы кинетических уравнений, выявили удовлетворительное согласие, свидетельствующее об адекватности использованных в работе моделей, описывающих процессы перераспределения энергии оптического возбуждения в примесной подсистеме исследуемого материала.

O14. Photon–photon Interaction in Structured QED Vacuum

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Currently, there is a rapid development in high-intensity laser technology through European research infrastructure — Extreme Light Infrastructure — that will make nonlinear quantum electro-dynamical (QED) vacuum effects accessible. In this report, in accordance with this achievement, we develop a new method for enhancement of vacuum polarization effects in strong fields employing periodically-structured field configurations, in particular, realized via parallel focused laser beams. In spatially modulated strong fields, vacuum acts like a nonlinear Kerr media with modulated third-order susceptibility. In the result, coherence effects arising in spatially structured vacuum that are associated with Bragg interference can enhance the vacuum polarization by a factor proportional to the square of the number of modulation periods within the interaction region. We investigate these coherence effects in photon–photon interaction (Kerr interaction) considering two channels of scattering of probe laser beam on the parallel focused lasers. Both processes of elastic and inelastic four wave-mixing in structured QED vacuum accompanied with the Bragg interference are investigated. In the case of the elastic scattering of photons, when the frequencies of probe wave ω_1 and scattered wave ω_2 are the same, the phase-matching condition is met $\mathbf{k}_1=\mathbf{k}_2+\mathbf{q}$, where $\mathbf{q}$ is the vector of the lattice. While, for inelastic light scattering with absorption or emission of additional laser photons i.e. for the processes: $\omega_1=\omega_2+2\omega_L$, $\omega_1=\omega_2-2\omega_L$ the phase-matching condition is accordingly modified $\mathbf{k}_1=\mathbf{k}_2\pm2\mathbf{k}_L+\mathbf{q}$. We assume the parallel laser beams are elliptic Gaussian to allow for a large overlap with the probe beam and simultaneously to fulfill the Bragg condition. Calculating the probabilities of light-by-light scattering, we analyze limitations imposed on the impinge angle, monochromaticity and the divergence of the scattering wave to achieve maximal enhancement effect. The feasibility of experimental realization of light-by-light scattering in configuration of parallel focused lasers with parameters envisaged in the future Extreme Light Infrastructure is also demonstrated.

O15. Coulomb Focusing at Above-threshold Ionization in Mid-infrared Strong Laser Fields

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Strong laser fields in a mid-infrared domain are becoming accessible due to recent advancement of optical parametric chirped pulse amplification which renewed the interest to the classical regime of the strong field processes with mid-infrared lasers. Recent experiments on the photoionization of atoms and molecules in strong mid-infrared laser fields reveal a characteristic spike-like low energy structure (LES) in the energy distribution of electrons emitted along the laser polarization direction. Employing a semiclassical model which incorporates nonperturbatively the Coulomb field effects, we identified the origin of the LES. Multiple rescattering of the ionized electron plays a decisive non-perturbative role. The transverse momentum change of the electron due to multiple forward scattering (FS) is shown to distort the electron phase space in such a way to create peaks at low electron energies. The Coulomb focusing is usually expected to decrease with increase in the laser intensity and wavelength. In this context, it was surprising that at large wavelengths of the mid-infrared laser field, the multiple FS played a decisive role for the creation of the LES.

We investigate how the contribution of different components of Coulomb focusing depends on laser intensity and wavelength. It is shown that the high-order FS can have a nonperturbative effect in Coulomb focusing. In some regions of ionization phase (photoelectron energy), the contribution of the higher-order FS to the total Coulomb focusing can dominate the lower-order one which creates local peaks in the photoelectron spectra. The effective number of rescattering events is shown to depend weakly on laser intensity and wavelength within the classical regime of interaction.

We have investigated also the role of multiple FS in a laser field of elliptical polarization. The yield of photoionization along the main axis of the polarization ellipse (scaled by the photoionization yield in a field of linear polarization) is shown to behave differently in the region of low-and high-energies. The effect is explained by the dominance of the multiple FS and the single FS in the low-and high-energy domain, respectively.

O16. Production of Fock States in Pulsed Anharmonic Oscillators

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It has been a longstanding goal in quantum optics to realize controllable sources generating quantum oscillatory states, particularly, number or Fock states. The preparation and use of such states forms the basis of quantum computation and communications. The direct preparation of oscillatory states is the difficult problem that is associated with the fact that classical excitations applied to an oscillatory system usually generate a coherent state, nearly indistinguishable from a classical state, but not quantum state. As it is proposed theoretically and demonstrated experimentally, the preparation of oscillatory Fock states, in that number, photonic states in optical cavities and the motional states of trapped and laser cooled ions is easily realized in interaction of oscillatory mode with atomic systems. In this case, quantum states are created under classical pulse applied to the atomic systems and then subsequently are transferred to the oscillatory mode.

In this report, we show that oscillatory Fock states can be created for an anharmonic oscillator without any interactions with atomic systems and in the presence of decoherence. For this goal we consider anharmonic dissipative oscillator under sequence of classical Gaussian pulses separated by time intervals. It is demonstrated that creation of Fock states can be realized in this system with complete consideration of decoherence effects and in the regime of strong Kerr nonlinearity when the number oscillatory states are well resolved. For this goal tuning transitions between vacuum state $|0\rangle$ and the number states $|n\rangle$, (n = 1, 2, 3, …), we demonstrate production of Fock states for definite time intervals in dependence of the system's parameters. As the system is more complicated to be solved analytically we use numerical methods. Investigation of the system allows finding the regimes when Fock states can be created with high fidelity. However, the system control does not allow generating any Fock state approved by anharmonic oscillator nature.

O17. Non-Markovian Quantum Dynamics to Control Decoherence: an Ancillary Qubit Can Help Increase the Fidelity of a Two-qubit Gate

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Quantum computing has been confronted by decoherence as the main obstacle to the achievement of entanglement of qubits and quantum operations with high fidelity. Markovian quantum dynamics leads always to decoherence, but the presence of active environments can give rise to a special class of controllable non-Markovian processes that might be used to mitigate the effects of decoherence.

Controlled collisions between cold atoms trapped in spin-dependent optical lattices were proposed more than a decade ago as a means to implement a two-qubit quantum phase-gate, a basic and universal building block for the construction of more complex quantum information processing systems with neutral atoms in optical lattices. The corresponding experimental demonstration has however been elusive and will rely not only on the ability to manipulate the atoms in an efficient and controlled way, but also on an accurate theoretical description of the interactions and the type of collision leading to the expected output.

Former theoretical models are based on a decoherence-free s-scattering description of the atomic collision. Due to the presence of the optical lattice, the atomic collision is in fact ruled by the dipole-dipole interaction. The quantum dipole-dipole interaction is mediated by the electromagnetic vacuum, which acts as a reservoir opening an infinite number of channels for transitions out of the two-qubit state space during gate operation and reducing strongly its fidelity. From this perspective, the electromagnetic interaction while being essential for the gate operation, constitutes a more serious drawback to quantum information processing with neutral atoms than does memory decoherence.

We consider three neutral atoms trapped in neighboring sites of a 1D spin-dependent optical lattice generated by two counter-propagating laser beams. The interatomic distance can be controlled by changing the polarization of the lasers, allowing for perfectly controlled atomic collisions that introduce different phase shifts to different initial vibrational states of the atoms, the results being a controllable phase gate. One of the atoms acts as an ancillary qubit, while the other two constitute a two-qubit phase gate.

The non-Hernmitian part of the effective quantum dipole-dipole interaction between two atoms in an optical lattice results in a non-Markovian space-modulated rate, which depends on the interatomic distance and is not always positive, implying transitions from and back to the two-qubit state space. Therefore, by introducing a third ancillary qubit, we can theoretically balance the decoherence effects of the environment and achieve full fidelity of the two-qubit gate operation.

We find a specific value for the closest atomic distance needed to achieve strong suppression of the decoherence due to gate operation. For this “resonance like” condition, the fidelity of the two-qubit gate with the attached third ancillary qubit is close to unity. We conclude that basic building blocks of neutral atom quantum computers should consist of at least three atoms in order to achieve high fidelity operation.

O18. Magneto-absorption in Ellipsoidal Quantum Dots

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We analyze the absorption of light in elliptical quantum dots in the presence of the perpendicular magnetic field. Using the effective mass approximation, the confining potential of the quantum dot is considered in the form

$$V_{conf}\left(x,y,z\right)=\sum_{i=1}^{3}\frac{\mu\omega_i^2 x_i^2}{2}, \tag{1}$$

where μ is the effective mass of an electron (hole), ω_i is the confining frequency for corresponding coordinate x_i. The interband optical transitions are studied first within the perturbation approach for weak magnetic fields. The same transitions are discussed for arbitrary values of the magnetic field within the analytically solvable model of elliptical quantum dot with N electrons [1], described by the Hamiltonian $H=\sum_{i=1}^{N}H_0(i)$,where a single-particle Hamiltonian is

$$\hat{H}_0=\hbar\Omega_+\left(\hat{a}_+^{\dagger}\hat{a}_+ +1/2\right)+\hbar\Omega_-\left(\hat{a}_-^{\dagger}\hat{a}_- +1/2\right). \tag{2}$$

Here $\hat{a}_i^{+}\left(\hat{a}_i\right)$ is a creation (annihilation) operator and

$$\Omega_{\pm}^2=\frac{1}{2}\left(\omega_x^2+\omega_y^2+4\omega_L^2\right)\pm\sqrt{\left(\omega_x^2-\omega_y^2\right)^2+8\omega_L^2\left(\omega_x^2-\omega_y^2\right)+16\omega_L^4}\ ,\ \left(\omega_L=\frac{eB}{2\mu c}\right). \tag{3}$$

The absorption coefficient of the quantum dot is calculated — as well as threshold frequency — as a function of the applied magnetic field. The selection rules for the interband transitions are found. Theoretical results obtained in the exactly solvable model demonstrate a good agreement with experimental data produced with the aid of the magneto-luminescence method in $In_{0.53}Ga_{0.47}As$ quantum dot [2].

We also discuss the excitonic effects in the perturbation approach, similar to the case of the rectangular confining potential [3].

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O19. Extracting Work from Microcanonical Bath: Entropy-Information Relation Revisited

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It is known that statistical physics provides the fundamental relation between entropy and the pragmatic information: the von Neumann entropy $S[\rho]$ for a quantum system described by a density matrix ρ determines (via the free energy formula) the maximal work (useful energy) that can be extracted from this system in contact with an equilibrium thermal bath. This relation is the basis for information-driven engines (Szilard's engine, Maxwell's demon) that extract work not via initially stored energy, but rather via initially stored information.

Here we show that this well-known relation between entropy and information is restricted to the canonical thermal bath only. For a microcanonical bath — which is arguably more fundamental concept of equilibrium — the form of the entropy–information relation should be revised by changing there the von Neumann entropy to the newly introduced linear entropy. In addition, for the microcanonical bath the very concept of relating the entropy to information (together with the free energy concept) gets limited for sufficiently low bath temperatures, because a system — starting from the canonical state ρ_T at the bath temperature T — can enhance the work extracted from the microcanonical bath without changing its state ρ_T.

O20. Surface Plasmon Radiation Damping Rate in the Metallic Nanosphere Interacting with Interface

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Metallic nanoparticles (MNP), especially noble metal particles demonstrate narrow optical resonances due to the surface plasmon (SP) oscillations. Depending on dielectric permittivity of the matrix and metal as well as the shape of MNP, the resonance frequency noticeably shifts, which makes them very perspective for biophysical applications. From this point of view the MNP near the interface is of special interest because of strong dependence of the SP frequencies on particle-interface separation [1–4]. This interest is conditioned by the possibility of using them in biosensing and labeling of macromolecules and using them as "nanorulers" for measuring distances in nanoscale.

It is clear that high enough spectral sensitivity of optical devices based on MNPs can be achieved only in case of sufficiently narrow resonances. In the biophysical applications the MNPs with the radii $R \geq 40$ nm are commonly used where the radiation damping rate (RDR), being proportional to R^3 [5] is a dominant relaxation mechanism. Consequently the problem of calculating the RDR in nanosphere near the interface becomes important. The resonance frequencies of MNP near the interface and RDR are determined numerically in [1]. However the developed method does not provide adequate description of the experimental data for the most important case of small separations.

It was proved recently that coupled nanospheres and the system "nanosphere near the interface" can be described analytically with good accuracy using the eliminated quadrupole moment approximation (EQMA) and its improved version [2]. In this communication we develop analytical approach to the theory of radiation damping of SP oscillations in nanosphere near the interface based on improved EQMA. Improvement of the accuracy of SP frequency calculation for smaller particle–interface separation is achieved by substituting the electric field of the nanosphere by the field of a dipole with finite arm chosen in a special way. By applying the electrostatic imaging method the boundary problem is transformed to the case of two interacting nanospheres described by the set of three equations. This set allows to determine the position and the arm of the dipole as well as the sought SP resonant frequencies as a function of the particle-interface separation. Using these data the RDR of the system is calculated in the frame of method developed in [4] for coupled spheres. It is shown that for the nanosphere and its image the superradiance effect does not take place and consequently RDR is of the same order of magnitude as for an isolated sphere.

It is shown that decrease of the RDR with decrease of particle–interface separation is conditioned not only by the SP frequency redshift, but also by the relation between the dielectric constants of adjacent media. For the particle-interface gap values as small as 0.03 of the sphere diameter the RDR can decrease by 30–40%.

It is proved that the range of applicability of the obtained analytical results is wider than those of [3,4] as well as of known numerical results [1].

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P1-1. Effect of a Subwavelength Layer on All-optical Diode Action in 1D Photonic Crystal

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It has been reported that introducing of a positive or negative-refractive index subwavelength layer in the 1D photonic crystal (1DPC) structure significantly affects the bistability threshold [1–2]. The difference in bistability thresholds creates favorable condition for unidirectional propagation so that 1DPC structure can be used as All-Optical Diode (AOD) [3]. It is expected that such a thin film in an asymmetric 1DPC structure will modify the AOD action by the structure. In this paper, we consider a subwavelength layer of conventional positive-index material in the nonlinear 1DPC and investigate the effect of its thickness on AOD action. We have used an asymmetric multilayer stack of $(BA)^5(AB)^5C(AABB)^5$, where A and B denote the alternative layers and C represents the subwavelength layer. A is a Kerr-type nonlinear medium with optical parameters of $n_A = 1.55$ and $\chi_A = 2.5\times10^{-5}\, cm^2/MW\,(9-BCMU)$ and B is a linear dielectric media with $n_B = 2.3$ and $\chi_B \approx 0$ (TiO_2). The quarter wavelength condition of optical thickness in both of A and B are applied in the numerical calculation. By using of the well-known transfer matrix method one can find the transmittance spectrum of the structure.

The electric-field intensity distribution in the structure from left to right and right to left is non-symmetric. The resonant peak of the transmission spectrum for different thickness of the subwavelength layer is also obtained. It is found that with increasing of the thin layer thickness the linear defect mode shifts to lower frequency which influences the threshold of optical bistability [4].

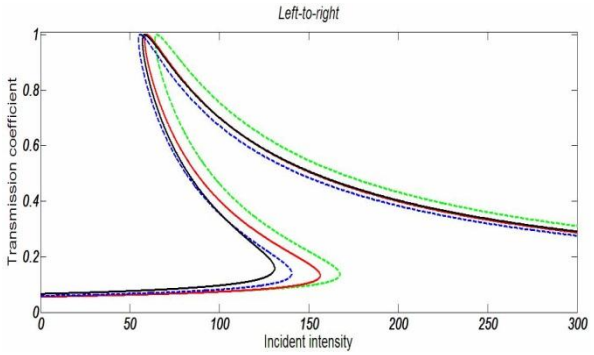

Fig. 1.

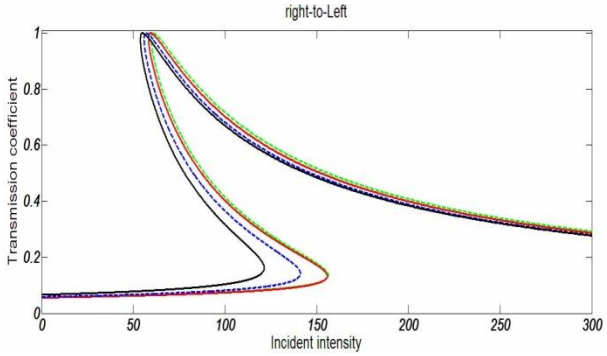

Fig. 2.

Figs. 1 and 2 show the AOD performance of structure under study for different subwavelength layer thickness of (green; $d_c = 0$, red; $d_c = \lambda/32$, blue; $d_c = \lambda/12$ and black; $d_c = \lambda/8$) for left-to-right and right-to-left incidents, respectively. The incident frequency is $\omega = 0.9935\omega_0$. It is shown that AOD action is different for various thickness of thin layer. The thin film of the subwavelength layer introduces an additional phase shift that affects the resonate condition and weakens the electric field intensity and the threshold of the optical bistability increases accordingly. The further results and discussion are presented in a full paper.

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P1-2. Experimental Investigation of Spectral Peculiarities of Multilayer System, Consisting of Dye Doped Polymer Film Sandwiched between Two Cholersteric Liquid Crystal Layers

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The creation of compact, easy processible, low threshold and tunable optical components and laser sources is in great demand in science and industry. One of the strategies for solving this problem are multilayer structures consisting of laser dye-doped polymer thin films, as solid active element and Cholesteric Liquid Crystals (CLC)-s as resonators.

In this work we have experimentally investigated optical properties of multilayered structure, consisting of two right handed CLC with the same pitch and Rhodamine 6G doped polymethyl metacrilate (PMMA) thin film. Particularly transmission and luminescence spectral peculiarities and their thermal dependences for this system were studied.

P1-3. Experimental Study of Optical Activity of Planar Chiral Structure Generated on the Surface of Azo Polymer Film

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Nowadays electron beam lithography is a technique commonly used to create 2D chiral patterns on the surface of dielectric material. This method is very difficult and expensive. In this paper we describe a simple experimental method for generation planar chiral patterns on the surface of azo polymer film. It has been shown that illuminating of an azo-polymer film with a single uniform laser beam can create the surface relief pattern on the surface of the film. This self-organized structure formation is very sensitive to the angle of incidence for 45° polarization direction and incidence angle 33° generation 2D chiral structure. A planar object is said to be chiral in two dimensions if it cannot be brought into congruence with its mirror image unless it is lifted from the plane planar. This structures consist of chiral elements the possess no line of symmetry in the plane of structure. Based on theoretical prediction, the first experimental works on the optical properties of planar chiral materials was carried out by Papakostas. Their experimental results demonstrated that planar chiral structures could affect the polarization state of light in a manner similar to 3D chiral media. In contrast to the case of 3D chirality, planar chiral materials exhibit an opposite handedness when viewed from opposite directions. Therefore planar chiral materials should induce opposite polarization changes for light transmitted and reflected through these structures in opposite direction. In experimental work, we demonstrate how polymeric 2D chiral patterns can change of polarization state of visible light transmitted and diffracted from the surface of asymmetrical patterns.

P1-4. Hexafluorosilicates of Amino Acids

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Salts of various amino acids (A) were objects of very intensive research in the last years. Simple salts of singly (A^+) and doubly (A^{2+}) charged cations as well as dimeric ($A...A^+$) cations with definite anions and mixed salts with different anions are known and studied.

We have discovered a new class of salts: hexafluorosilicates of amino acids.

In this presentation we report our preliminary results on salts of various amino acids resulted in reaction with hexafluorosilicic acid (H_2SiF_6). H_2SiF_6 exists in the form of SiF_6^{2-} anions and protonated water in its crystal hydrates and even in aqueous solution [1].

Four types of simple salts have been obtained:

1) $2A^+.SiF_6^{2-}$ (the majority of salts, e.g. $2Gly^+.SiF_6^{2-}$, $2L\text{-}His^+.SiF_6^{2-}$, etc.),
2) $A^{2+}.SiF_6^{2-}$ (e.g. $L\text{-}His^{2+}.SiF_6^{2-}$, $L\text{-}Lys^{2+}.SiF_6^{2-}$, $L\text{-}Orn^{2+}.SiF_6^{2-}$),
3) $2(A...A^+).SiF_6^{2-}$ (e.g. $2(Bet...Bet^+).SiF_6^{2-}$),
4) $A^+.(A...A^+).SiF_6^{2-}$ (e.g. $L\text{-}Ala^+.(L\text{-}Ala...L\text{-}Ala^+).SiF_6^{2-}.H_2O$).

In addition to these simple salts we have obtained also some mixed salts with different anions: $2L\text{-}His^{2+}\cdot 2BF_4^-\cdot SiF_6^{2-}\cdot 2H_2O$, $2L\text{-}His^{2+}\cdot 2ClO_4^-\cdot SiF_6^{2-}\cdot 2H_2O$, anhydrous $2L\text{-}His^{2+}\cdot 2Cl^-\cdot SiF_6^{2-}$ and $2L\text{-}His^{2+}\cdot 2Br^-\cdot SiF_6^{2-}$, etc. as well as $2L\text{-}His^{2+}\cdot X(1)^-\cdot X(2)^-\cdot SiF_6^{2-}\cdot 2H_2O$ type salts.

Salts of optically active amino acids have noncentrosymmetric structures and can display piezoelectric and nonlinear optical properties, while some of them having polar symmetry also pyroelectric properties.

In addition, they can find application also in dentistry as preparations having anti-carious activity [2].

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P1-5. Аномальное фазообразование в ходе получения плёнок Er_2O_3 методом электронно-лучевого напыления

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Методом электронно-лучевого напыления в вакууме были получены кристаллические плёнки Er_2O_3 на подложках из стекла, сапфира, кремния и иттрий-алюминиевого граната. В зависимости от условий получения плёнки кристаллизовались в кубической и гексагональной структуре. Исследовались структурные, оптические и электрические свойства полученных плёнок.

P1-6. Charge Waves in Double Doped Photochromic Lithium Niobate Crystals

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Проведены экспериментальные исследования пространственно-временных характеристик фоторефрактивного и фотохромного эффекта в кристаллах ниобата лития легированных железом медью и железом марганцем. Обнаружены фотоиндуцированные автоволны изменения коэффициента поглощения при освещении ограниченной области кристалла излучением с длиной волны 488 нм. Экспериментально наблюдаются переход динамической системы из устойчивого состояния на фазовой плоскости в замкнутую фазовую траекторию с возникновением предельного цикла. Наблюдаются бифуркации с распадом фазовой траектории на два с меньшей площадью фазовой траектории.

P1-7. Электронные фазовые переходы металл–изолятор в широкозонных полупроводниках ZnO

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Широкозонный полупроводник оксид цинка (ZnO) обладает множеством интересных свойств и представляет интерес для технических приложений. Плёнки ZnO могут быть использованы для создания светодиодов и лазеров, работающих в сине-зелёном и УФ диапазонах. На их основе можно создать прозрачные дисплеи и преобразователи солнечного излучения. Введение акцепторной или донорной примеси позволяет управлять величиной и типом проводимости этих плёнок. В представленной работе, исследуются электронные фазовые переходы металл-изолятор в широкозонных полупроводниках ZnO и влияние неравновесных фотовозбуждённых носителей заряда на процесс транспорта. Рассматривается влияние дефектного комплекса, обусловленного кислородной вакансией – междоузельного атома цинка, на переход металл-изолятор. Получены и исследованы особенности перехода металл–изолятор в легированных Li или Ga плёнках ZnO.

P1-8. Structural and Electrical Properties of La-based Oxide Structures

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Progressive DRAM cell technology requires new dielectric materials for capacitor applications. Silicon dioxide, silicon nitride and HfO_2 have been commonly used as dielectric materials in metal–insulator–metal (MIM) capacitors. But the capacitance densities are limited due to their low dielectric constants and films showed a leakage current problem. Use of the high-*k* dielectrics can solve such problems by enhancing the capacitance density. One of the best candidates for use in a DRAM storage capacitor is hexagonal La_2O_3 owing to a large energy band gap (5.5 eV), high electrical breakdown field strength and high dielectric constant (k = 27).

In this work within the framework of the hexagonal lanthanum oxide (h-La_2O_3) formation, lanthanum hexaboride (LaB_6) film was oxidated at different temperatures (700–1060°C) under reduced atmosphere pressure (1×10^{-2}—1.5×10^{-1} Torr) during 30 min. Crystallographic evolution of LaB_6/La_2O_3 structure versus annealing temperature and pressure has been studied using XRD, FIR reflectivity spectroscopy, SEM and X-ray microanalysis (EDS).

After hydratation of $Al_2O_3/LaB_6/La_2O_3$ structure in de-ionized water for 960 min and post-annealing at 900°C under 1.5×10^{-1} Torr, the La_2O_3 film showed high k value ~ 22, in spite of the presence of lanthanum carbonate $La_2O_2CO_3$ and lanthanum hydroxide $La(OH)_3$ species.

P1-9. The Study of Peculiarities of CeB_6 Crystals Chemical Composition for the Purpose of Creating a Single-photon Detector of UV and X-ray ranges

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The precise determination of the chemical composition of samples is extremely important for understanding many physical phenomena and peculiarities of property changes in almost all compounds. The ratio of main elements and the presence of uncontrollable impurities are the main factors determining most physical properties. It is especially hard to conduct a precise chemical analysis of compounds containing light and heavy atoms, even more so to determine the change in their ratio in microvolumes while scanning the surface of samples. In this work we discuss the EDX results of CeB_6 crystals obtained by different growth methods, taking into account their surface roughness. We calculate the corrections one should apply to the experimental EDX results, depending on the standard arithmetic mean roughness amplitude R_a and the inclination angle α of the studied surface area to the horizontal, i.e. the parameters determining the surface roughness. We determined the precise values of R_a and α from the profilometry results. The obtained results have been used to determine the change in the B/Ce ratio along the length of the studied crystals and the content of uncontrollable oxygen and aluminum impurities, with the purpose of developing the selection criteria of samples used in creating a single-photon thermoelectric detector of the UV and X-ray ranges.

P1-10. Modelling the Kinetic Processes Occurring in the Sensor of a Thermoelectric Detector upon Absorbing a Single Photon

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As we have shown earlier [1,2], the sensors of a thermoelectric detector based on Au:Fe or on rare-earth hexaborides are capable of detecting single photons of UV and X-ray ranges. This paper describes the propagation of heat upon absorbing a photon in different areas of the absorber of the thermoelectric detector with different geometries of the absorber, the heat sink and the thin-film thermoelectric bridge linking them, as well as the temperature gradient and the voltage arising on the thermoelectric sensor. The calculations were made for cases where the thermoelectric sensor is Au:100 ppm Fe at 0.3 K, $(La_{0.99}Ce_{0.01})B_6$ at 0.5 K and CeB_6 at 9 K.

The results will be used in creating a working model of a thermoelectric single-photon detector.

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P1-11. Infrared Down-conversion Luminescence in $LiNbO_3:Er^{3+}$ Excited by Short Pulse Radiation at 980 nm

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Down-conversion luminescence in the $LiNbO_3:Er^{3+}$ crystal at a wavelength of 1500 nm, as well as luminescence at 1010 nm under pulsed excitation of different power at a wavelength of 980 nm are experimentally and theoretically studied. It is revealed, that the main part of the absorbed energy gives rise to the luminescence at 1500 nm. Considered concentrations of Er^{3+} impurity ions allow to exclude cooperative processes in the impurity subsystem. The experimental results are interpreted in the framework of a three electronic levels system, assuming that the population of the higher lasing level $^4I_{13/2}$ in the crystal under study is caused by down conversion processes. It is shown that for obtaining of a laser radiation at about 1500 nm one can effectively use a pulse-pumping at 980 nm with a power density in a range of 50–60 MW/cm^2.

P1-12. Evidence of Multiparticle Optical Centers in $LiNbO_3:Er^{3+}–Yb^{3+}$ Crystal

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Кристаллы $LiNbO_3:Er^{3+}–Yb^{3+}$ широко используются в качестве источников излучения и усилителей мощности лазерного излучения на длине волны 1.5 мкм во всемирной паутине оптических коммуникаций. Поэтому поиску оптимальных условий работы и улучшению выходных характеристик этих активных сред направлены усилия многочисленных исследовательских групп во всем мире.

Одной из характерных особенностей этого материала является предрасположенность его структуры образовывать сложные многочастичные оптические центры, состоящие из двух и даже трёх близкорасположенных примесных ионов уже при достаточно низких концентрациях легирующих примесей. Этим обуславливается высокая вероятность различных кооперативных процессов в примесной подсистеме кристалла $LiNbO_3:Er^{3+}–Yb^{3+}$, имеющих существенное, а при определённых условиях, и определяющее влияние на эффективность и динамику заселения энергетических уровней, ответственных за получение генерации вблизи 1.5 мкм.

В настоящей работе приведены результаты исследований, направленных на выявление и определение особенностей проявления таких многочастичных центров в характеристиках люминесцентных сигналов кристалла $LiNbO_3:Er^{3+}–Yb^{3+}$. Посредством селективного выбора длины волны возбуждения осуществлено раздельное возбуждение различных типов оптических центров: так, например, длина волны 808 нм способна возбуждать лишь оптические центры с наличием ионов Er^{3+}, длина волны 1064 нм — только с ионами Yb^{3+}, а длина волны 980 нм — типы оптических центров как с обоими ионами. Посредством применения метода спектроскопии временного разрешения проведены исследования кинетических характеристик люминесцентных откликов этого материала, а также изучены зависимости интенсивностей этих люминесценций от интенсивности оптической накачки на указанных длинах волн. Сравнение экспериментальных результатов с численными расчётами, проведёнными на основе балансных уравнений, оставленных в рамках определённых моделей процессов, имеющих место в примесной подсистеме, позволило оценить количество многочастичных оптических центров и степень их влияния динамику формирования населённостей энергетических уровней примесей.

P2-1. Время-частотное распределение излучения разностной частоты сгенерированного в поле лазерного импульса длительностью в несколько оптических колебаний распространяющегося в кристалле GaAs с периодической доменной структурой

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Рассмотрен процесс генерации излучения разностной частоты в кристалле GaAs с периодической доменной структурой в поле лазерного импульса длительностью в несколько оптических колебаний в режиме слабо выраженной хроматической дисперсии.

Методом прямых получено численное решение системы связанных нелинейных дифференциальных уравнений в частных производных, описывающих эволюцию электрического поля лазерного импульса с длительностью в несколько колебаний в кристалле GaAs как с периодической так и с апериодической доменной структурой.

С помощью преобразования Вигнера исследовано время-частотное распределение как для y-поляризованного фемтосекундного лазерного импульса распространяющегося в кристалле GaAs с периодической доменной структурой, так и для z-поляризованного импульсного излучения разностной частоты, полученного в результате фильтрации z-поляризованного импульса на выходе кристалла.

P2-2. Generation of Terahertz Radiation in Nonlinear Crystals Placed Within a Hollow Waveguides

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The results of the THz pulse generation via optical rectification of pico- and femtosecond laser pulses in nonlinear crystals are presented. Detection of THz pulse are performed at room temperature by both Schottky diode and ZnTe crystal. The quantum efficiency of energy conversion up to 28% of maximum value is obtained with Schottky diode.

P2-3. Similariton-based Spectral Interferometry for Femtosecond Pulse Characterization

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The signal analysis problem on the femtosecond time scale employs the powerful arsenal of contemporary optics, involving the methods of nonlinear and adaptive optics, Fourier optics and holography, spectral interferometry, etc. The pulse direct measurement is possible by the transfer of temporal information to the space or frequency domain. The approach of pulse spectrotemporal imaging through temporal lensing [1] by its recent implementations in the silicon chip [2] and similariton-induced parabolic temporal lens [3] provide accurate, high-resolution direct measurement of a pulse in the spectrometer as in the femtosecond optical oscilloscope. Many scientific and technological problems, however, along with the amplitude, demand also the phase information, motivating the urgency of methods for the complete characterization of femtosecond signal. The nonlinear-optical techniques of FROG and its modifications [4], provide complete determination of the temporal amplitude and phase by recording high-resolution spectrograms, which are further decoded by means of iterative phase-retrieval procedures. The approach of spectral interferometry (SI*)* [5] and its extensions to the methods of SPIDER [6], SPIRIT [7], and SORBETS [8] have the advantage of non-iterative phase retrieval.

The classic SI is based on the interference of the signal and reference beams spectrally dispersed in a spectrometer, with the spectral fringe pattern caused by the difference of spectral phases [5]. The known spectral phase of the reference permits to retrieve the spectral phase of signal, and, together with its spectrum measurement, to recover the complex temporal amplitude of the signal through Fourier transformation. The setup of classic SI is rather simple, and the measurement is accurate as any interferometric one, but its application range is restricted by the bandwidth of the reference. The SI characterization of a signal that has undergone a nonlinear interaction with medium requires a special broadband reference to fully cover the broadened signal spectrum. To avoid this restriction, the self-referencing methods of spectral shearing interferometry are developed [6-8]. This improvement promotes the SI-methods to the class of the most popular and commercialized methods of accurate measurements on the femtosecond time scale at the expense of a more complicated optical arrangement. The reporting method of similariton-based SI, along with its self-referencing performance, keeps the simplicity of the principle and configuration of the classic SI. The key peculiarity of similariton, important for its application to SI, is its known - parabolic phase.
In our developed method of similariton-based SI, we split the signal beam, injected its part into a fiber and generate the nonlinear-dispersive similariton-reference. The residual part of the signal, with a relevant time delay, is coupled with the similariton in a spectrometer. The spectral fringe pattern, on the background of the signal and similariton spectra, completely covers the signal spectrum, and the whole phase information becomes available. The known spectral phase of the similariton-reference allows to retrieve the signal spectral phase, and by measuring also the signal spectrum, to reconstruct the complex temporal amplitude of the signal through Fourier transformation. Thus, the method of similariton-based SI joins the advantages of both the classic SI [5] and spectral shearing interferometry [6-8], combining the simplicity of the principle and configuration with the self-referencing performance.

Experimentally examining the similariton-based SI, we compare the measurements with the ones carried out by a prototype of the femtosecond oscilloscope (FO) based on the pulse spectrotemporal imaging in the similariton-induced temporal lens. The resolution of such a similariton-based FO is given by the transfer function of the similariton's spectrum [3,9], and FO with a similariton-reference of the bandwidth of 50 THz bandwidth provides the 7-fs temporal resolution of direct measurement of temporal pulse in a spectrometer. In the comparative experiments, we have demonstrated the similariton-based SI and FO as two applications of similariton. Both the reference-based methods become self-referencing by the use of similariton. In our experiment, we have generated nonlinear-dispersive similaritons of up to 50 THz bandwidth, and characterized them by means of chirp measurement through the technique of frequency tuning in spectral compression process, stating that only fiber dispersion determines the phase of broadband nonlinear-dispersive similariton. Afterwards, we have demonstrated the similariton-based method of SI for complete characterization of set of different femtosecond pulses in the comparative experiments with the FO-measurements.

Concluding, our comparative study, carried out together with the theoretical check and autocorrelation measurements, evidences the quantitative accordance and high precision of both the similariton-referencing methods of SI and temporal lensing. The FO provides direct pulse measurement, but it does not give phase information without additional interferometric measurement. The self-referencing method of similariton-based SI provides the complete and accurate characterization of femtosecond signal.

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Р2-4. Исследование нелинейного взаимодействия электромагнитного излучения с объёмным зарядом в вакуумных электронных приборах

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Для успешного освоения терагерцового (ТГц) диапазона волн необходима разработка высокочувствительных, быстродействующих, доступных приёмников и преобразователей излучения, работающих при комнатной температуре [1].

Нелинейные свойства вакуумных электронных приборов хорошо известны, однако они не нашли применения для регистрации и преобразования излучения ТГц и оптического диапазонов. Это в основном связано с тем, что из-за больших размеров (по сравнению с длиной волны) прибор становится системой с распределёнными параметрами, из-за чего возникает проблема подвода электромагнитного излучения к электродам. Однако, эта проблема автоматически снимается при обеспечении проникновения электромагнитной волны в межэлектродное пространство. В этом случае электромагнитная волна фактически распространяется в нелинейной среде, созданной неоднородно распределённым объёмным зарядом вблизи термоэмиссионного катода. Происходит взаимодействие волны с объёмным зарядом во всем межэлектродном пространстве, в результате чего можно получить нелинейное преобразование излучения, в частности — детектирование.

В настоящей работе проведены исследования нелинейного взаимодействия электромагнитных волн СВЧ, субтерагерцового и оптического диапазонов с неоднородно распределённым объёмным зарядом вакуумных электронных приборов. В качестве источников излучения в СВЧ и субтерагерцовом диапазонах были использованы стандартные генераторы, а в оптическом диапазоне — разные лазеры (непрерывный He–Ne ($\lambda \approx 0.63$; 1.15; 3.39 мкм), импульсный неодимовый ($\lambda \approx 1.06$ мкм), фемтосекундный лазер ($\lambda \approx 710$–950 нм), с частотой повторения ~80 МГц).

Исследовались вакуумные диоды и триоды с наиболее удобной конструкцией электродов для ввода электромагнитной волны в межэлектродное пространство.

При использовании вакуумного диода было получено уверенное детектирование излучения как в СВЧ ($F \approx 10$ ГГц) и субтерагерцовом ($F \approx 0.14$ ТГц) так и оптическом ($\lambda \approx 1.06$ мкм) диапазонах волн.

Чувствительность триода выше по сравнению с диодом, за счёт внутреннего усиления триодом детектированного сигнала, получаемого на сетке. Благодаря этому получается уверенное детектирование как субтерагерцового излучения, так и относительно слабого излучения (≈ 1 мВт) He–Ne лазера в ИК и видимой области.

Вакуумные приборы способны выдержать большие мощности электромагнитного излучения, следовательно, их можно использовать также в качестве нелинейного элемента в преобразователях частоты. Эффективность преобразования можно увеличить за счёт увеличения области взаимодействия.

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P2-5. The Effects Temperature on Optical Gain in GaN Based Quantum Dot Laser

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In this article the effects of temperature on optical gain and also the possibility of lasing at high temperatures for GaN based Quantum dot laser has been investigated. The GaN quantum dots have been located in AlGaN barrier materials with different Al molar fraction. One of the most temperature dependent parameter in the lasers is the electron relaxation time. At high temperatures polar optical phonon scattering is dominant because GaN is a highly polar material. To calculate the electron relaxation time at high temperatures, the polar optical scattering of electron has been calculated**.** The material gain per QD layer of a QD laser is expressed as [1]:

$$g(\hbar\omega) = \frac{\pi e^2}{n_b c \varepsilon_o m_0^2 \omega} \int_{-\infty}^{\infty} dE' |M_{env}|^2 |e.P_{cv}|^2 D(E') B(E', \hbar\omega)[f_c(E', F_c) - f_v(E', F_v)]$$

term ω is the angular optical frequency, n_b is the background refractive index of material, c is the speed of light in free space, ε_0 is permittivity of free space, m_0 is the free electron mass, and E' is the optical transition energy. The term $|M_{env}|^2$ is the envelop function overlap between the QD electron and hole states. The term $|e.P_{cv}|^2$ is the momentum matrix of QDs. The term $D(E')$ represents the inhomogeneous broadening of QDs, which works as a density of states of QDs. The term B shows the homogenous broadening of Lorentz shape as:

$$B(E' - \hbar\omega) = \frac{\frac{\hbar\Gamma_{cv}}{\pi}}{(E' - \hbar\omega)^2 + (\hbar\Gamma_{cv})^2}$$

where FWHM is given as $2\hbar\Gamma_{cv}$ with the scattering rate. Time scattering depends on temperature. When the scattering time differs, density of states and homogenous broadening differ and that is a result of changing of maximal gain with temperature. The modeling results show that the maximal gain decreases as temperature increases. That is induced by decreasing of scattering time with increasing the temperature [2].

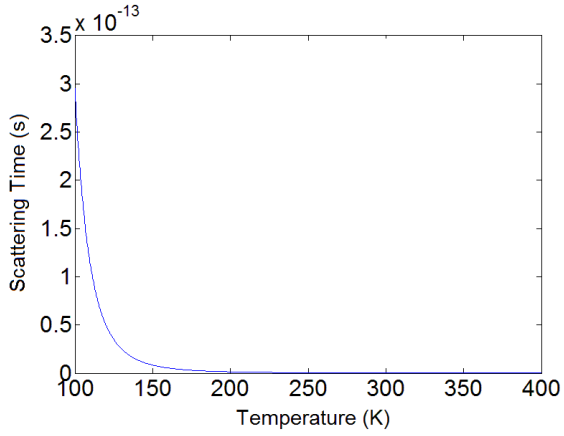

Fig.1. The scattering time versus temperature for $Al_{0.2}Ga_{0.8}N$/GaN QD.

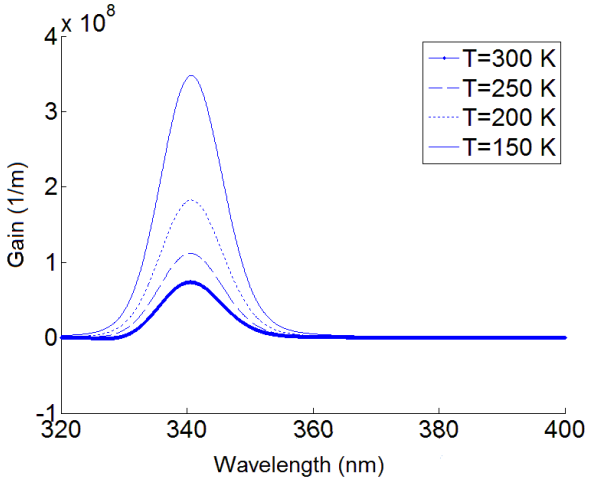

Fig.2.The gain versus wavelength for $Al_{0.2}Ga_{0.8}N$/GaN QD lasers.

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P2-6. Near and Far Field Optical Patterns Formation by Rotational Symmetry Masks: Application to Optical Spatial Soliton Generation

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The existence and stability of spatial optical solitons — self-trapped optical beams of finite spatial cross-section that travel without divergence — are the subject of increased interest due to numerous possible applications, particularly, for controlling of optical beam propagation, in optical communication systems, for all optical switching etc. Many properties of optical solitons that cannot be observed in bulk uniform nonlinear media have been discovered in nonlinear planar waveguide [1], in nonlinear medium with ring-shaped [2] and square photonic lattices [3]. Another way to form the optical solitons in nonlinear medium is the use of necklace ring beams with intensity periodically modulated along the azimuthal direction [4].

In this report we present the formation of necklace type optical beams by rotational symmetry masks technique developed in [5]. The detailed studies of space evolution of optical beam formation from near field to far field by 633 nm laser beam with the use of 7-fold symmetry mask were performed for the first time. The mask had ~35000 holes with the distance of ~30 μm between ~10 μm holes. Different types of necklace beams with different numbers of "pearls" periodically or quasi-periodically situated along the different radii rings were observed during space evolution of optical diffraction pattern (Fig.1).

Additionally, annular disposed multiple "pearls" necklace beams was formed in the far field from 5, 6, 8 and 9- fold symmetry masks by red 633 nm 17 mW and green 532 nm 50 mW single mode laser beams.

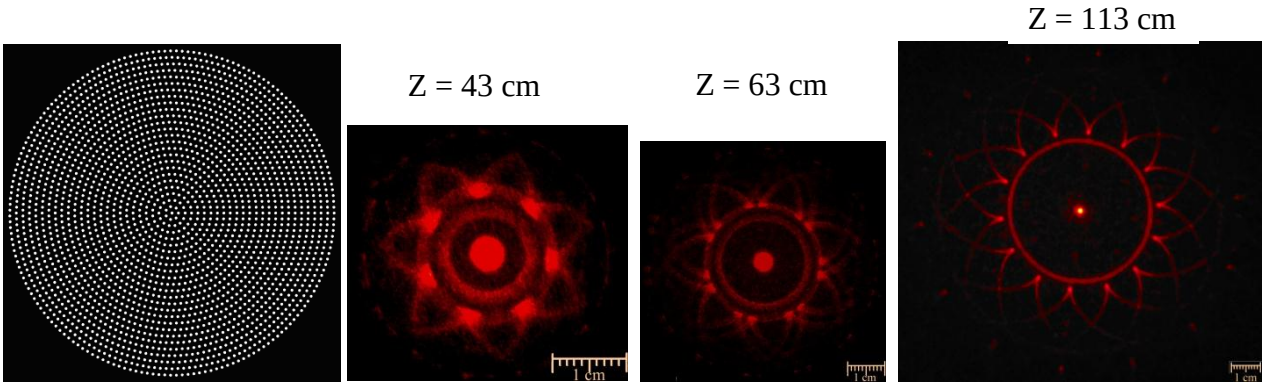

Fig.1. (a) Fragment of 7-fold symmetry mask. (b)–(d) Space evolution of diffraction pattern in the direction of beam propagation Z at different distances from the mask, Z = 43, 63, 113 cm, respectively. The scale of 1 cm in the (b) is two times larger compared with (c)–(d).

The necklace beams can be used for formation of spatial solitons in nonlinear solid crystals, such as lithium niobate, lithium tantalate, strontium barium niobate, in liquid crystals and in resonant atomic media.

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P2-7. Оптические уравнения Блоха и пространственная динамика поляризации света

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Как хорошо известно, динамика спина во внешнем магнитном поле описывается уравнением Блоха, которое позволяет рассматривать такие явления как спиновая прецессия, магнитный резонанс, спиновое эхо и т.д.

С другой стороны, использование лазерных источников позволило и в резонансной оптике также наблюдать аналогии многих этих явлений: затухание свободной поляризации, оптическую нутацию, фотонное эхо и т.д. Заметим, эти явления теоретически описывались, как принято называть, оптическими уравнениями Блоха [1].

Во многих работах (см. [2]), в том числе и в наших (см. [3,4]), продемонстрирована возможность описания пространственной динамики состояния поляризации света при распространении в средах с неоднородностями анизотропии и гиротропии с помощью уравнений Блоха.

Из самых последних работ можно отметить [5], где с помощью аналогии между уравнениями когерентно возбуждённого двухуровневого атома и уравнений для поляризационных параметров Стокса (аналог уравнений Блоха) найдено точное аналитическое решение для двух различных моделей неоднородной анизотропной среды. Это хорошо известные модели Ландау-Зенера и Демкова-Кунике.

В настоявшей работе нами рассмотрена задача распространения поляризованного света в неоднородной среде с пространственно модулированной диэлектрической проницаемостью и линейной гиротропией. В качестве частного примера рассмотрена пространственная динамика состояния поляризации света в холестерическом жидком кристалле с переменным шагом.

Задача анализирована в рамках поляризационных уравнений Блоха [5]. Аналитическое решение задачи проведено в приближении вращающейся волны.

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P3-1. Experimental Investigation of the Writing Beam Coherence on Self-Organized Patterns Formed on Azo Polymer Film

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There have been plenty of studies on polymers containing Azo dyes to make use of them in fabricating holographic gratings in order to apply them in information storage, light-waveguide coupling and also in nonlinear optical electronics. In this regard it is possible to design 2 and 3D reflection gratings and to organize material properties in such a way that self-organized gratings show desired effects. In all these cases, the gratings are made from the resultant interference pattern from laser lights with a wave length that can be absorbed by the media. Recently, surface relief gratings have been made by illuminating single beam laser light on the surface of Azo polymer films.

Studies show that the coherence of writing light has the essential role in creation of self organized surface relief gratings. The coherent light of a laser can create a self-organized surface relief grating with an almost steady period and amplitude under illumination, while incoherent light is not able to do so. The recent works have shown that a background incoherent light can increase the growth rate of the gratings under illumination of a coherent light, which enables us to create self-organized gratings with even lower powers of coherent light.

In this experimental work, alternations of the spatial coherence degree of the writing laser light using rotating ground glass have been investigated. A partially coherent light field is achieved via passing a focused laser light through rotating ground glass. By varying the illuminated area on the rotating ground glass and changing the size of speckle, we investigated the subsequent changes in the spatial coherence degree of the laser light. In order to do this we used interference patterns of one or more aperture in a mask.

Then by manipulating the coherence degree of writing laser light, variations in self-organized surface relief gratings are studied. By reducing the speckle size, the diameter of the coherent area decreases consequently and this makes the self-organized surface relief gratings to be formed in a smaller domains, thus needing more time to propagate to the whole area of illumination. Therefore, gradually the time that it takes for the growth rate of the grating to start surging increases. This process continues until we get to a speckle size of 0.37 mm, a size in which the grating is no longer formed and this point serves as a threshold for formation of self-organized surface relief gratings.

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P3-2. Birefringence Enhancement via Quantum Interference in the Presence of Magnetic Field

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We investigate the linear magneto optical rotation (LMOR) in a V-type three-level quantum system. The linear polarized probe field is applied to the system. We apply an external static magnetic field to establish birefringence due to asymmetric indices for left and right circular polarization components of the probe field. Such birefringence implies a rotation to the direction of the polarization of the probe field, leading to the magneto-optical rotation (MOR). We assume two transitions are coupled to the common vacuum field and then induce the quantum interference in spontaneous emission of upper levels. We study, analytically and numerically, the birefringence in this system in the presence the quantum interference due to the spontaneous emission. It is shown that the birefringence property increases by taking to account the quantum interference effect. Moreover, it is demonstrated that the Doppler broadening has a destructive role in birefringence enhancement.

P3-3. Ultrashort Pulse-generation in the Induced Optical Anisotropic Medium

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The possibilities for the medium's coherent response accumulation method are studied in order to amplify the rotation of probe beam polarization in two-photon resonance conditions.

We discuss a gas medium of three-level atomic systems, with the first excited energy level splitted into two magnetic sublevels, in a combined "probe + pump" field. This model is the most convenient for discussions with alkali metals. Here the far off the resonance, monochromatic, strong pump field connects the excited doublet $nP_{1/2,3/2}$ with the higher excited energy level $n'S_{1/2}$ and the far off the resonance, weak probe field connects the ground state $nS_{1/2}$ of the atom with an excited doublet $nP_{1/2,3/2}$. All the calculations are done in two-photon ("probe + pump") resonance conditions.

Here we have received an analytical expression for the output probe field in the dipole and rotated wave approximation.

We have shown that by coherent shifting of input probe field's phase from 0 till π and vice-versa for the rotated component of the output probe field we can get an isolated, about 5 times narrowed light impulse with more than 16 times amplified intensity.

P3-4. Laser-induced Thermomechanical Effects in Nematic Liquid Crystal

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Liquid crystals (LC) have always been an interesting medium for both theoretical and experimental physicists because of their big nonlinearity, sensitivity to external fields, reasonably cheap costs, applicability etc. It was always interesting to devise new techniques to reorient the director of LC. There are several mechanisms allowing us to convert absorbed energy by LC to the energy of reorientation of director. One of them is thermomechanical effect. There are three types of thermomechanical effects. The first effect is the hydrodynamic flow caused by the temperature gradient, the second one is the temperature change due to non-uniform flow and the third one is additional director reorientation due to temperature gradient. The third type thermomechanical effect induced by Gaussian beam was recently studied both theoretically and experimentally. Many studies were published showing the existence of thermomechanical hydrodynamic flow in hybrid and cylindrical-hybrid cells. Thermomechanical flow induced by static electric, magnetic and laser fields in the presence of temperature gradient has been also studied both theoretically and experimentally in planar and homeotropic cells. It was shown that thermomechanical effects can decrease the threshold of Fréedericksz transition in dye-doped nematic liquid crystal (NLC). One of the big advantages of thermomechanical effect compared with other mechanisms (for instance giant optical nonlinearity (GON)), which are absent in the case of normal incidence of laser beam, is that it emerges at any angle of incidence of laser beam. Thermomechanical effects were also studied in NLC, containing azobenzene in their molecular structure. It was suggested that one of the mechanisms of optical nonlinearity observed in the experiment in such medium may be thermomechanical effect.

P3-5. Convective Motions in Nematic Liquid Crystal Homeotrop and Planar Cells Induced by Gaussian Laser Beam

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Laser beam heating the medium induces instability in the liquid crystal (LC) cell. This instability in conjunction with influence of gravitational force results in convective motions in the cell. In this paper theoretical modeling for studying convection induced by Gaussian laser beam in nematic LC homeotrop and planar cells is presented for the first time. Velocity field and LC director distribution are obtained for various light powers and LC cell sizes by solving Navier-Stokes, heat transfer and director equations simultaneously. The modeling allows us to solve the problems of convections induced by Gaussian laser beam due to Rayleigh-Benard and Marangoni mechanisms as well. There is a good qualitative agreement between theoretical and prior experimental calculations. The possibility of control and stability of convective motions are studied. Benard cells become unstable when the light intensity is high. These instabilities are of thermal origin because the Prandtl number for the medium under study is considerably larger than unity.

P3-6. Second Harmonic Generation Modeled by the Demkov-Kunike Resonance-crossing Configuration

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We present a rigorous analysis of second harmonic generation in finite-length phase-modulated medium within the approximation of coupled planar wave two-mode model. We derive a simple, yet highly accurate, approximation for conversion coefficient for the Demkov-Kunike resonance-crossing model. Analyzing the dependence of the conversion efficiency on the nonlinear susceptibility and phase-mismatch modulation we show that high conversion is achieved for certain regions of these parameters. We show that in the case of large enough phase-mismatch the conversion efficiency almost monotonically increases depending on the nonlinear susceptibility. However, we show that for a fixed value of the final phase-mismatch the conversion coefficient always remains limited by a maximal conversion efficiency less than 100%, in contrast to the known Landau-Zener prediction.

P3-7. Study of the Rb Dark-line atomic resonance splitting in a Strong Magnetic Field

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Recently we reported about high contrast Electromagnetically Induced Transparency (EIT) resonance (also called Dark-line) obtained with the help of nanometric-thin cell (NTC) of the thickness $L = \lambda = 794$ nm, on the Rb D_1 line [1]. The high contrast EIT resonance of 40% allows us to study, for the first time, the Dark-line splitting in a very wide range of magnetic B-fields of 1-2000 G. Extremely small thickness of NTC is favorable for the use of widely available permanent magnets, which significantly facilitates application of strong magnetic fields.

For Dark-line formation two extended cavity diode lasers (forming the coupling and probe beams) with $\lambda = 794$ nm and 1 MHz line-width are used. The coupling laser frequency is resonant with ^{87}Rb D_1 line, $F_g = 2 \rightarrow F_e = 2$ transition, while the probe laser frequency is scanned across $F_g = 1 \rightarrow F_e = 1,2$ transitions. The Dark-line resonance splitting for $B < 100$ G provides 5-fold better spectral resolution as compared with that obtained in [2].

Although in the case of strong B-field six EIT components are expected to exist, however for $B > 700$ G only two Dark-line components remain. There is a good agreement between the experimental results and the theory.

It is important to note, that the amplitude of the Dark-line component strongly depends on the detuning of the coupling laser frequency from the appropriate intermediate (6P) hyperfine level. However, by the coupling laser frequency appropriate detuning it is possible to provide selective addressing of the increase the amplitude of needed Dark-line component.

Well resolved Dark-line components can be used for magnetometry with local nanometric spatial resolution.

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P3-8. Intensity-dependent Features in Hydrogen-buffered Cesium Spectra

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As it was shown earlier, the presence of Ne or H_2 buffer gas significantly modifies the intensity dependence of cesium resonant absorption and fluorescence [1,2], which was attributed to resonant excitation-induced chemical reaction [2].

In this presentation we report the observation of a spectral feature, namely a dip (peak) in transmission (fluorescence) excitation spectra of a room temperature cesium cell with addition of 20 Torr of H_2 appearing between Doppler-broadened $F_g = 3 - F_e = 2,3,4$ and $F_g = 4 - F_e = 3,4,5$ hyperfine transition groups of Cs D_2 line when laser radiation intensity exceeds 10 mW/cm^2. In the experiment we have implemented frequency modulation of the diode laser radiation with lock-in detection of the transmission and fluorescence signals. Spectra taken at different intensities are presented and compared with the spectra without the buffer gas. Possible physical mechanisms responsible for the observed distinction are discussed.

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P3-9. Analysis of High Excited "Hot" Bands of the SO_2 Molecule

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The main goal of the present study is to analyze rotational structures of highly excited "hot" vibrational bands, $v_1+2v_2-v_2$ and $2v_2+v_3-v_2$, $v_2+3v_3-v_2$ and $2v_1+v_2+v_3-v_2$, and $v_2+2v_3-v_2$. All of these bands are located in the region of considerably stronger bands, $v_1 + v_2$ and $v_2 + v_3$, $3v_3$ and $2v_1+v_3$, and $2v_3$, respectively. On that reason, as the first step of analysis, we made assignments of transitions belonging to these strong bands. As the result of analysis, we were able to assign three times more transitions to the bands $v_1 + v_2$, $v_2 + v_3$, and $3v_3$ (3360 transitions with $J^{max.} = 78$ and $K^{max.}a = 27$ to the band $v_1 + v_2$, and 2380 transitions with $J^{max.} = 69$ and $K^{max.}a = 24$ to the band $v_2 + v_3$, and about 2200 transitions with $J^{max.} = 60$ and $K^{max.}a = 19$ to the band $3v_3$) and four times more transitions to the $2v_1+v_3$ and $2v_3$ bands (about 2300 transitions with $J^{max.} = 69$ and $K^{max.}a = 20$ to the band $2v_1+v_3$ and more than 4500 transitions with $J^{max.} = 76$ and $K^{max.}a = 26$ to the band $2v_3$) than it was known in the before literature.

After "cleaning" the experimental spectrum from transitions belonging to the strong bands, assignment of transitions of "hot" bands was made on the basis of calculation scheme derived in Ref. [1]. As the result, 1230 transitions with $J^{max.} = 60$ and $K^{max.}a = 20$ were assigned to the band $v_1+2v_2-v_2$, and 990 transitions with $J^{max.} = 59$ and $K^{max.}a = 16$ were assigned to the band $2v_2+v_3-v_2$, and 230 transitions with $J^{max.} = 35$ and $K^{max.}a = 10$ to the band $v_2+3v_3-v_2$, and 115 transitions with $J^{max.} = 26$ and $K^{max.}a = 11$ to the band $2v_1+v_2+v_3-v_2$, and 885 transitions with $J^{max.} = 32$ and $K^{max.}a = 17$ to the band $v_2+2v_3-v_2$.

The set of spectroscopic parameters, determined from the fit of all the obtained energy levels, reproduces experimental line positions with the accuracy close to experimental uncertainties. Obtained results can be used in different both pure scientific, and applied problems of physics, chemistry, astrophysics, etc.

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P3-10. Influence of Unequal Oscillator Strengths on Stimulated Raman Adiabatic Passage through Bright State

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The problem of the coherent control of atomic states, preparation of atoms in a stable superposition state, and atomic population transfer has attracted much attention in the last decade. One of the main motivations is associated with the rapid development of the field of quantum computing. One of the key problems of quantum information processing is the construction of given coherent superposition atomic states in a macroscopic volume. Stimulated Raman adiabatic passage (STIRAP) [1] is considered to be the most common method for atomic population transfer in quantum systems. Being analyzed in detail on various quantum systems from both theoretical and experimental points of view, this method is widely adopted for the implementation of tools as optical devices for atomic beams, control of chemical reactions, high-precision magnetometry, atom cooling, etc.

Meanwhile, an alternative method for population transfer, based on the intuitive pulse sequence with large one-photon detunings was demonstrated in [2]. In contrast with the STIRAP method, where the population transfer is realized via a dark state, the population transfer for the intuitive pulse sequence is obtained via a bright state. The authors of [2] called the atomic population transfer of this kind b-STIRAP. A detailed theoretical analysis of the b-STIRAP process in media with equal oscillator strength on adjacent transitions was performed in [3]. However, it is well-known that an oscillator strength ratio different from unity can considerably impact on the coherent processes in Λ-media (see e.g. [4]).

In the present work an analytical and numerical analysis of the b-STIRAP process in a medium with unequal oscillator strengths is performed. It is shown that the length of population transfer can be considerably increased by an appropriate choice of the dipole transitions.

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P3-11. Interference Phenomena at the Elastic Collision of Atoms in Laser Field With Formation of Feshbach Resonance and Allowance for Inelastic Decay Channel

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Interference effects in the elastic collision of atoms with allowance for inelastic decay channel with formation of the Feshbach resonance in the laser field are considered. Resonant laser radiation leads to additional channels of elastic and inelastic scattering which are strongly coupled with each other. The cross sections of the elastic and inelastic scattering are obtained and the interference between resonant and nonresonant scattering is analyzed.

P3-12. Constructing Specified Coherent Superposition States of Atoms in Macroscopic Volume

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Creation of needed coherent superposition states of atoms is a key problem of quantum informatics. In spite of huge number of theoretical studies on efficient transfer and control of atomic level populations, all of them are mainly concentrated on microscopic processes in isolated atomic systems. Meanwhile, at propagation of laser pulses in resonant media energy transfer occurs unavoidably between these pulses, which may result in essential changes in time envelopes, in parametric broadening of spectra, in breaking of the interaction adiabaticity, and, hence, loss of control of populations. In the present work we use relatively simple quasienergy technique in STIRAP-b-STIRAP chains to study the possibilities of producing controllable superposition states preserving their stability at propagation of pulses in media.

P4-1. Physical Properties of the Pulsed-laser Deposited Sb-pSi and aC-Sb-pSi Surface-barrier Structures

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Surface-barrier structures of Sb-pSi and aC-Sb-pSi were fabricated by the vacuum deposition of Sb (~5 nm) and amorphous carbon (~100 nm) films onto factory quality p-type (>10^4 Ohm·cm) Si substrate (500 μm) at the room temperature by the using of a Q-switched glass:Nd^{3+} laser (1.064 μm wavelength, 30 ns pulse duration, intensity of ~10^9 W/cm^2 in the target irradiation zone). Electrical properties (current-voltage and capacitance-voltage) of these structures were studied. Current density-voltage characteristics of fabricated structures were investigated in the dark and under white light illumination at room temperature. Short-circuit current density J_{sc} = 1 mA/cm^2 and open-circuit voltage V_{oc} = 0.2 V for Sb-pSi and correspondingly 6 mA/cm^2 and 0.26 V for aC-(Sb)-pSi junctions were obtained. The mechanisms of carrier flow across the fabricated junctions were analyzed.

P4-2. Hypericin-specified Destruction of Collagen Fibers Revealed by Multiphoton Microscopy

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Collagen is the most widespread structural protein in higher vertebrates. It comprises about 6% of body weight in mammals and, as an important component of extracellular matrix in tissues, performs important physiological functions in cell migration, proliferation, differentiation, and growth. Many kinds of diseases are related to pathological changes of collagen fibers, including tumorogenesis and metastasis of neoplastic cells, keloid, myocardial infarction, cirrhosis, pulmonary and other types of fibrosis. The destroying of collagen fibers in controlled manner is of high importance for biomedicine. Earlier, we showed that hypericin (Hyp), a natural pigment extracted from plant *Hypericum Perforatum* (зверобой) was capable to penetrate into collagen fibers and photochemically induce quenching and spectral redshift of collagen fluorescence, whereas many other photoactive agents like chlorine e6, hematoporphyrin, etc., did not produce any change in collagen optical properties. Here, using multiphoton microscopy, we show that hypericin–collagen interaction results partially irreversible destruction of collagen fiber.

Multiphoton, particularly, second harmonic generation (SHG) microscopy with advantages of being label-free, inherent three-dimensional resolution, lower photodamage, have already proved as effective approach for quantification of accumulation [2], thermal denaturation [3] and femtosecond laser destruction [4] of collagen fibers. In the current work, it is shown that the treatment of collagen fibers by Hyp-ethanol solution for 20–30 min. dramatically decreases in collagen fiber SHG intensity. After elution of Hyp, SHG signal recovers by 15–20% (See Fig. 1). We believe, that collagen SHG degradation by Hyp is associated with the hydrogen-bond-breaking and irreversible destruction of non-centrosymmetric structure of native collagen fibers, and increasing in two-photon fluorescence can be explained by formation of new fluorescent molecular bonds [4].

Kinetics and optimal condition of collagen fiber destruction by Hyp will be presented.

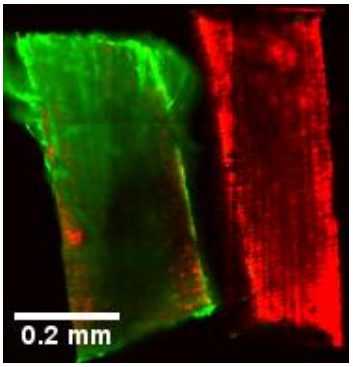

Fig.1. Multiphoton imaging of collagen fibers from chicken leg tendon. Left fiber was treated with Hyp-ethanol solution, and right fiber was treated with pure ethanol for 30 min. Green is pseudo-color of two-photon excited florescence registered in 420–600 nm spectral region, and red is SHG registered in 380-400 nm band. Excitation laser: Ti-Sa femtosecond laser (780 nm, 100 fs, 2 mW, 80 MHz).

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P4-3. Investigation of Metal-dielectric Composite Materials for Excitation of Surface Plasmon Polariton in Terahertz Range

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Terahertz (THz) waves show great potential in many scientific research and application fields, such as spectroscopy, free space communication, environmental sensing, imaging for biomedical and security purposes [1]. Nowadays THz technology moves toward the component integration and it has become essential to develop THz waveguides with strong subwavelength field confinement and low losses. In visible and infrared regions the concept of surface plasmon polaritons (SPP) is commonly used for strong optical field confinement. The SPP is quasi-two-dimensional electro magnetic excitations, propagating along a dielectric–metal interface and having the field components decaying exponentially into both neighboring media [2]. In THz region the dielectric permittivity of metals has large imaginary part which dominates over its negative real part. This implies that SPP are weakly bound to the surface and can hardly be used for the confinement of THz radiation [3]. This problem can be overcome by use the materials having plasma frequency lower than that of metal. One of the promising ways is the use of composite materials, which are formed by embedding metal particles in dielectric material.

In this report, we focus on mixture of Al, Cu, and Co powders and lacquer. All these materials are cheap and widely commercially available. Besides the mixture fabrication process is distinguished by easiness of fabrication and good reproducibility in wide range of the metal filling factor *f*. The complex dielectric constants of composite materials were measured by Time Domain Spectroscopy (TDS) setup in transmittance and reflectance modes in the frequency range 0.1–2.5 THz. We observe that the metal–dielectric composites show different characteristics, depending on the metal fill fraction *f*, that fall into one of three distinct regimes. In the "metallic" regime, in which *f* is large ($f > 0.6$), the composite could support conventional SPP mode (real part of dielectric constant is negative), but it has high propagation losses and low confinement. In the "dielectric" regime (real part of dielectric constant is positive), in which *f* is small ($f < 0.4$), the composite could not support any surface modes. In the intermediate "quasi-metallic" regime ($0.4 < f < 0.6$), the composite material supports a SPP mode with relatively low propagation losses and strong field confinement, that is different from that of a "metallic" regime. The measured refractive indexes are compared with values calculated by effective medium approximation (EMA) model. The experimental and theoretical results are in good agreement for small values of $f < 0.35$. At the same time we noticed disagreement that exists for large values of *f*. It is probably related to the imperfection of EMA model and difficulty of homogenous composites fabrication with large metal fill fraction *f*.

In conclusion it has been demonstrated that fabricated metal-dielectric composites have negative real part of the effective dielectric permittivity and they can support SPP mode in THz range with relatively low propagation losses.

This work was partially supported by NFSAT Grant ECSP-09-42 and State Committee of Science of Armenia.

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P4-4. Investigation of CuO Ceramic Samples Properties before and after Influence of Laser Radiation

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One of the means of changing the microstructure, composition, physical properties of solids and likewise stabilizing metastable states is the influence of laser radiation. In this work we investigated the influence of laser radiation on surface morphology, composition and electrical conduction of copper oxide ceramic samples, which were synthesized under different conditions. Some of them were covered by copper film and subjected to additional thermal treatment. Laser processing of crystal surfaces was carried out by the radiation of a YAG:Nd laser's second and third harmonics. The X-ray microanalysis of samples was performed by the INCA Energy 300 microanalysis system. We have studied the temperature dependence of resistivity and the volt-ampere characteristics of the samples within the 77–300 K temperature range. Starting from certain values of increasing voltage an avalanche-like increase of current was observed, which does not depend on its direction. It was discovered that the $R(T)$ dependence of samples changes both by additional thermal treatment and by influence of laser radiation.

P4-5. Methods for Pulsed Laser Deposition of Large-area Films Using More than One Target

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For tackling the new problems arising in modern applied science and hi-tech fields it becomes more and more important to synthesize new materials in different forms, particularly, in the form of large-area films and coatings. The pulsed laser deposition method allows one to obtain high-quality films of semiconductors, dielectrics, metals and alloys of multicomponent compounds. We have developed special techniques for depositing thin films on rotating disks and translationally-moving ribbons. In this paper we propose new solutions, which employ more than one target for deposition, allowing in case of a rotating disk substrate to shorten the deposition duration and in case of a ribbon substrate — to increase the ribbon width or the speed of depositing a film of the same thickness. Apart from pulsed laser deposition, the proposed methods are applicable to all methods of deposition from a point source.

P4-6. Femtosecond Pulse Compression: Managing and Optimization of the Pulse Asymmetry

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Despite the achievements of contemporary ultrafast laser technology, the technique of pulse compression is of interest till now, especially for generation of few-cycle pulses. In the systems of pulse compression, the positive parabolic phase obtained in a normally dispersive single mode fiber is compensated by the negative phase obtained in a dispersive delay line [1,2]. However, on the femtosecond timescale, the high-order nonlinear and dispersive effects are substantially limiting the pulse compression ratio, and the impact of residual third-order dispersion (TOD) between fiber and dispersive delay is the most substantial among all high-order effects. In our experiment [3], the residual phase compensation is carried out using the fact that the signs of TOD in fiber and prism compressor are opposite. However, such phase compensation limits the parameters of fiber and prism compressor, and thus, the compression ratio.

We report the results of numerical studies of phase compensation in the pulse compression process via shaping of asymmetric pulses at the system input. In this case, an effective pulse compression can be achieved, with a ratio corresponding to the pulse spectral broadening in fiber. This opportunity is caused by the fact that self-phase modulation in fiber results in a phase given by the pulse shape. We carry out simulations for fiber lengths around ~0.5 m, and for various types of asymmetric pulses. We achieve pulse compression ratio of ~10, for the spectral broadening factor of 10, and also compression ratio of ~20 for 26^X spectral broadening for asymmetric pulses at the system input, in the result of our studies. Thus, the pulse compression efficiency can be increased by TOD compensation through pulse asymmetry manipulation at the fiber input.

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P4-7. Relativistic Formulation of Moiré Fringes for Moving Periodic Structures

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When two periodic patterns are superimposed, moiré pattern is generated. The moiré bands will move if we displace the revealing layer. When the revealing layer moves perpendicularly to layer lines, the moiré bands move along the same axis, but several times faster than the movement of the revealing layer.

We study the effect of moving grating on the moiré fringes. We assume one of grating moves, respect to another one, with relativistic speed. The obtained moiré fringes are formulated according to the relativistic theory of light. The moiré fringes of such moving grating are studied and it is shown that, for relativistic velocity of grating, the displacement of moiré fringes happens with a speed higher than the velocity of light in vacuum. Moreover, it is demonstrated that the moiré fringes displacement depends on the relative direction of gratings as well their step difference.

P5-1. Controlling the Negative Refractive Index in a Four-level Atomic System via Applied Fields

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We propose a scheme for realizing negative refractive index [1] in a four-level atomic system. It is shown that the negative refractive index can be achieved in a wide frequency band based on the effect of quantum coherence [2,3]. It is also found that the single-negative index material can be converted to double-negative index material just via the intensity of coupling field. The two coherent coupling fields creates atomic coherence, and the weak probe field drives transition $|1\rangle \rightarrow |4\rangle$.

Fig. 2 shows the real parts of permittivity and permeability versus the probe field detuning. It can be realized that the real part of permittivity is negative for different values of Rabi frequency Ω. For $\Omega = 3\gamma$ the permeability is positive, while it changes to negative as Rabi frequency changes to $\Omega = 4\gamma$, and back to positive for $\Omega = 5\gamma$. So for single negative refractive index can be changed to double-negative index just by adjusting the intensity of coupling field.

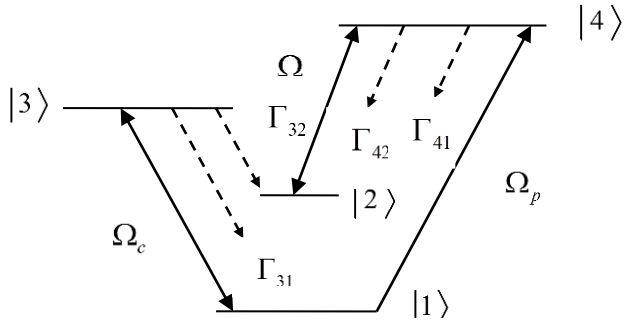

Fig. 1. Schematic diagram of a four-level atomic system.

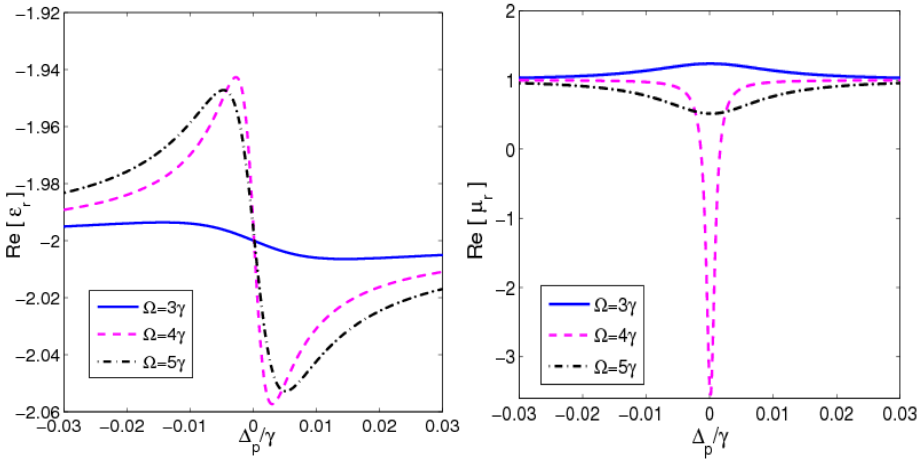

Fig. 2. The real parts of permittivity and permeability as a function of the of probe field detuning. The selected parameters are: $\Omega_p = 0.01\gamma, \Omega_c = 0.1\gamma, N = 2.5\times10^{25} m^{-3}, \Gamma_{42} = \Gamma_{32} = \gamma, \Gamma_{31} = \Gamma_{41} = \Gamma_{43} = 0.5\gamma$ and $\gamma = 2\pi \times 5.746 \times 10^6 Hz$.

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P5-2. Controlling the Probe -absorption and -dispersion via Quantum Interference from Incoherent Pumping Field in the Four-Level Atomic System

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[2]University of Bonab, Iran

We investigate the dispersion and the absorption behavior of a four-level Λ-type atomic system via atomic coherence induced by spontaneous decay and incoherent pump processes (Fig. 1). The effect of quantum interference arising from spontaneous emission and incoherent pumping field on light propagation is then discussed. Here, the probe absorption and dispersion from two fold lower-levels to upper level can be understood by two dressed states created by a strong coupling field [1,2]. Both the lower levels $|1\rangle, |2\rangle$, and upper level $|3\rangle$ are coupled by a weak probe laser field. An incoherent pump field ε pumps the system from two lower levels $|1\rangle$ and $|2\rangle$ to upper level $|3\rangle$ with the pumping rates r_1 and r_2. In addition, level $|4\rangle$ is coupled to the upper level $|3\rangle$ by a coherent coupling laser field. A typical absorption and dispersion curves are displayed in Fig. 2. It can be realized that the slope of dispersion can be changed from negative to positive as the interference parameters change from 0 to 1. We also find that probe absorption changes to probe amplification.

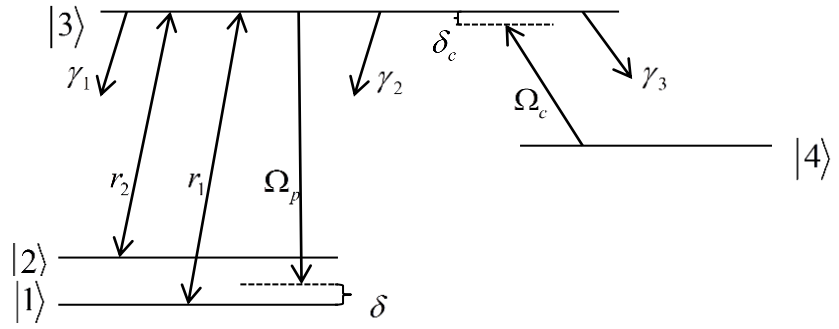

Fig. 1. (a) A four-level Λ-type atomic system.

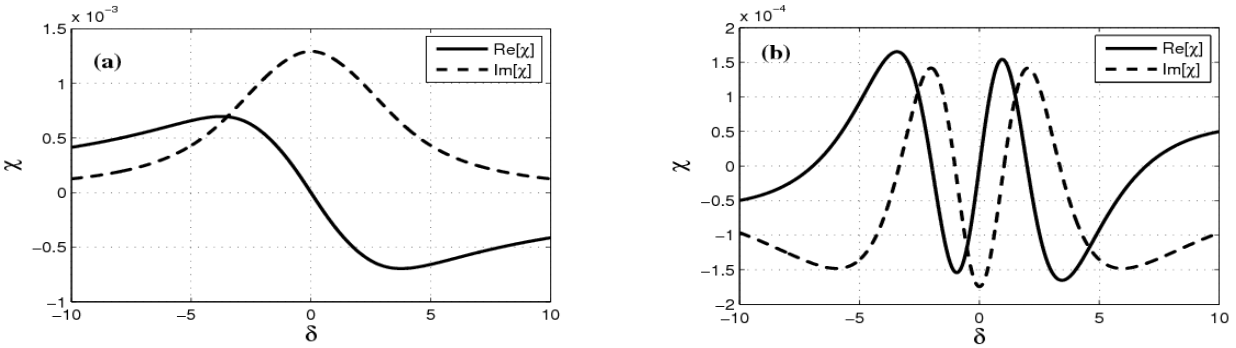

Fig. 2. Real and imaginary parts of susceptibility (a, b) versus probe field detuning for the parameters $\gamma_1 = \gamma_2 = 2\gamma$, $\gamma_3 = 0.1\gamma$, $\Omega_{p_1} = \Omega_{p_2} = \Omega_p = 0.01\gamma$, $\Omega_c = 1.5\gamma$, $\delta_c = 0$, $\omega_{12} = 2\gamma$, $r_1 = r_2 = 1\gamma$, $k = 0$ (a) and $k = 1$ (b).

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P5-3. The Effect of Electric and Magnetic Fields on the Bound Polaron States in the Cylindrical Quantum Wire with Finite Confining Potential

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The great progress in the last years of modern technologies in crystal growth has motivated studies of low dimensional semiconductor structures such as quantum well wires (QWWs). An understanding of the phonon modes effects, nature of impurity states and fields effects in semiconductor structures is one of the crucial problems in semiconductor physics [1–4].

In this paper we study the hydrogenic impurity binding energy in cylindrical quantum well wire including both barriers of finite height and applied electric and magnetic fields are studied with taking into account phonon confinement effect. The polaron effects on the ground-state binding energy are investigated by means of Landau-Pekar variation technique [5]. It has been shown that the polar optical phonon confinement leads to a considerable enhancement of the polaron effect and these corrections increase with increasing of applied fields. The results of the polaronic effects on the binding energy are obtained as a function of the applied electric and magnetic fields for different positions of the impurity.

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P5-4. Giant Kerr Nonlinearity via Interacting Dark Resonance States

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The linear and nonlinear response of a driven four-level Λ -type atomic system with two fold lower-levels is investigated. It is shown that the interaction of double dark resonance states lead to enhancement of Kerr nonlinearity. It is also found that the linear and nonlinear absorption property of the medium can significantly be modified via interacting dark resonance states. Therefore, enhanced Kerr nonlinearity without absorption occurs for certain probe field detuning. In addition, the effects of controlling parameters such as relative phase between applied field, and the intensity of driving fields on linear and nonlinear absorption as well as Kerr nonlinearity are then discussed.

P5-5. Optical properties of four level medium via spontaneously generated coherence

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In this paper, we investigated phase effect of spontaneously generated coherence (SGC) on transient and steady state behavior of weak probe field in Y-type four-level atomic system in the presence of two coupling fields. It is found that the probe absorption can be vanished and converted to probe gain in the absence of population inversion. Also it is shown that relative phase between couplings fields can influence the probe gain. Moreover, it is investigated that dispersion slope can be changed from positive to negative via spontaneously generated coherence.

Consider a four-level Y-type atom as shown in Fig.1. A pump laser field with frequency ν_2 and Rabi-frequency $\Omega_2 = \wp_{23}.E_2/\hbar$ drives $|3\rangle \rightarrow |2\rangle$ transition. Another coupling laser with frequency ν_1 and Rabi-frequency $\Omega_1 = \wp_{24}.E_1/\hbar$ is applied on the transition $|2\rangle \rightarrow |4\rangle$. A probe laser with frequency ν_p and Rabi-frequency $\Omega_p = \wp_{12}.E_p/\hbar$ drives $|2\rangle \rightarrow |1\rangle$ transition. The spontaneous decay rates from levels $|1\rangle$ and $|4\rangle$ to level $|2\rangle$ are denoted by $2\gamma_1$ and 2γ. Corresponding decay rate from $|2\rangle$ to $|3\rangle$ is also denoted by $2\gamma_2$.

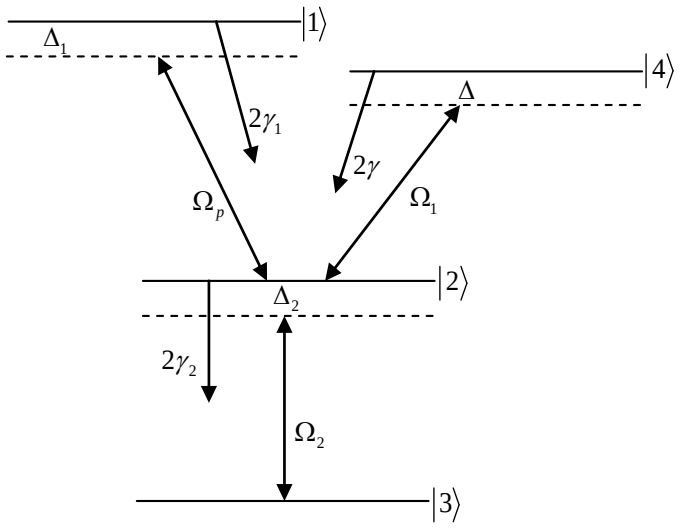

Fig. 1.

P5-6. Absorptive and Dispersive Properties of Four-Level Tripod Atomic Medium via Incoherent Pumping Field

Seyyed Hossein Asadpour[1], *Hamed Mahrami*[2], *Hamid Reza Hamedi*[1], *Mostafa Sahrai*[1], *Rasoul Sadighi-Bonabi*[3]

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In this paper, the effect of incoherent pumping field on absorption and dispersion of a weak probe field is investigated. It is shown that incoherent pumping field can reduce the absorption spectrum and change the slope of dispersion from positive to negative. Therefore, group velocity of light pulse can be controlled from subluminal to superluminal just by coherent and incoherent pumping. Also, it is found that probe absorption or amplification without population inversion depends on intensity of incoherent pumping.

Model

The conserved atomic system, i.e. there is no decay to states outside this system, and is shown in Fig.1, which can exhibit double electromagnetically induced transparencies. Three lower states $|1\rangle$, $|2\rangle$ and $|3\rangle$ are coupled near-resonantly to the excited state $|4\rangle$ by the probe field with carrier frequencies υ_1 and Rabi-frequency $\Omega_1 = E_1 \cdot \vec{\wp}_{41}/\hbar$, the control field with frequency υ_2 and Rabi-frequency $\Omega_2 = E_2 \cdot \vec{\wp}_{42}/\hbar$ and the another control fields with frequency υ_3 and Rabi-frequency $\Omega_3 = E_3 \cdot \vec{\wp}_{43}/\hbar$. Here $\vec{\wp}_{ij}$ are the atom dipole moments and $E_{2,3}$ (E_1) are the amplitude of the coupling (probe) fields. γ_{41}, γ_{42} and γ_{43} denote the population relaxation decay rates from the excited state $|4\rangle$ to the lower states $|1\rangle$, $|2\rangle$ and $|3\rangle$, respectively. The transition $|1\rangle \rightarrow |4\rangle$ is also pumped by an incoherent pumping field with pumping rate *r*.

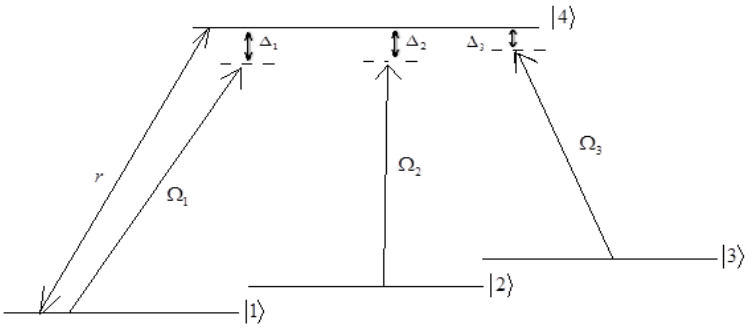

Fig. 1.

P5-7. The Disordering Effect on the One-Dimensional Aperiodic Optical Superlattice in Multi-Frequency SHG

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Yerevan State University, Armenia

The phase dependence between interacting waves in the parametric processes of nonlinear optics area is important so that the phase balance plays a significant role on the output efficiency of the process. The phase balancing in nonlinear optics is called phase-matching. Sometimes, the wave-vector mismatch appears as an oscillating phase that averages out the outing waves which is called "phase mismatch." There are different methods for satisfying phase-matching condition, including birefringence and quasi-phase-matching (QPM). QPM is a technique for phase matching nonlinear optical interactions. In this method the relative phase is corrected at regular intervals using a structural periodicity built into the nonlinear medium. Recently, multi-frequency (MF) second harmonic generation (SHG) process in aperiodic optical superlattice (AOS) is considered as a new source of frequencies. The effect of presence of linear domains in the nonlinear optical superlattice in SHG process is studied [1,2]. Different optimization methods are used to design AOS structure in parametric processes. One of the appropriate algorithms is simulated annealing (SA) [3]. There are various parameters which have effects on the output efficiency of the process one of which is fluctuation in length of layers of AOS. Therefore, the effect of the additional random length on the output efficiency is analyzed by considering linear-nonlinear AOS. In this article we introduce a combination of linear and nonlinear domains in AOS which is called PZNZ (+, 0, −, 0) model. By considering the random lengths for each domain and using the second harmonic field in SHG and SA method the SHG system efficiency rises by increasing the number of the segments. Also increasing fluctuation in length of domains tends to decrease of output efficiency and presence of linear media improves the output efficiency (Figure 1).

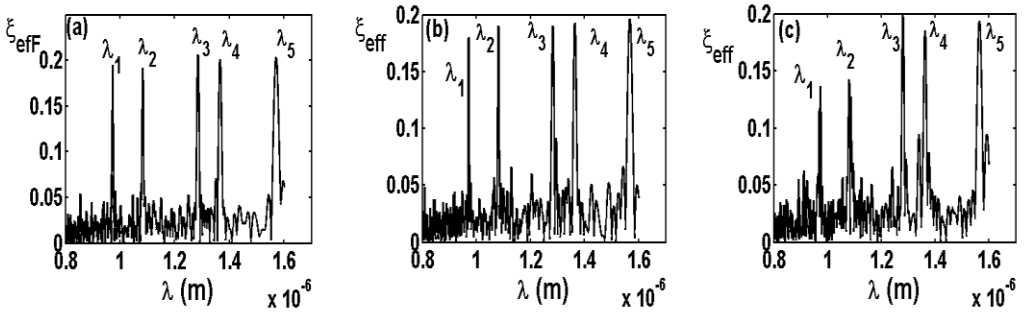

Fig.1. The behavior of the reduced effective nonlinear coefficient in constructed fluctuated AOS structure in PZNZ model. (a) The assumed amount of fluctuation is 5% of each domain's designed length; (b) The assumed amount of fluctuation is 10% of each domain's designed length; (c) The assumed amount of fluctuation is 20% of each domain's designed length. The assumed length of nonlinear and linear segments are $l_1 = 3\mu m$ and $l_2 = 0.1\mu m$ respectively and horizontal axis's interval is 0.00016 μm.

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P5-8. Multi-frequency SHG Process in the Presence of Disordered Two-dimensional Aperiodic Optical Superlattices

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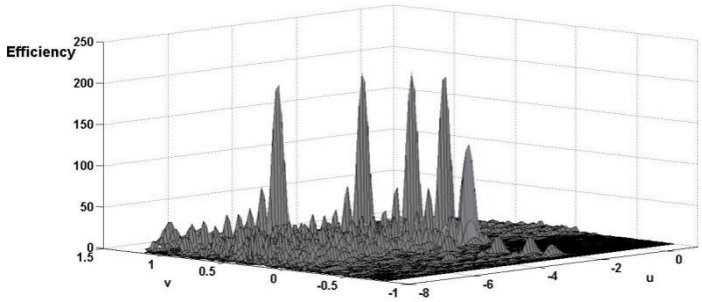
Second harmonic generation (SHG) in layered structures in nonlinear optics is one of the significant processes. The output efficiency for new produced frequencies critically depends on the phase-matching between interacting waves. Different phase-matching (PM) methods are performed including birefringence and quasi-phase-matching (QPM). In QPM method phase matching in optical interactions is corrected at regular intervals using periodic structures built in the nonlinear medium. Recently, multi-frequency (MF) SHG process in aperiodic optical superlattice (AOS) is considered as a new source of frequencies [1]. MF is the process in which more than one frequency in the output of AOS on the SHG process is achievable. Two-dimensional optical superlattice maintain PM condition in nonlinear interactions, therefore two-dimensional aperiodic optical superlattice (2-DAOS) can be used as a source of MF processes [2]. Different optimization methods are used to design AOS in optical parametric processes. One of the appropriate algorithms in this case is simulated annealing (SA) [3]. With the help of SA method we can design optimized 2-DAOS to have new SH frequencies in SHG. Various parameters have effects on the output efficiency of the process, one of which is fluctuation in length of layers of AOS. Therefore, in this paper the effect of the additional random length on the output efficiency is analyzed in nonlinear AOS. By considering, the random lengths for each domain and using the second harmonic field in SHG and SA method, the effect of fluctuation in length of layers on the SHG efficiency is studied which investigates a decreased output efficiency. Also, by increasing the number of the segments the output efficiency of fluctuated structure increases.

Gray scale diagram of 2D-AOS



The output efficiency of multi-frequency SHG process in fluctuated 2DAOS

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P5-9. Optical-theorem-based Study of Perturbative Scattering in *N* Dimensions

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According to wave-mechanical theory of elastic collisions in *N*-dimensional space [1], the scattering solution of the Schroedinger equation can be represented in the asymptotic region as a superposition of the incoming plane wave and the outgoing hyperspherical wave. Within the framework of the Born approximation, the low-energy ($E \to 0$) structure of the scattering amplitude, $f_{Born}(N, E)$, has been previously studied for higher dimensions ($N > 2$) [2] on the basis of the Lippmann-Schwinger equation and Green's function technique. In the present contribution, the objective is to show how the properties of $f_{Born}(N \geq 1, E)$ can be obtained by utilizing the information encapsulated in the *N*-dimensional version of the optical theorem [3]. In contrast to prior findings [2], our results reveal that the structure of $f_{Born}(N, E)$ obeys the constraints [4], which are imposed on the perturbative scattering process by isometric property of the *S*-matrix. We also discuss the changes occurring in the low-energy behavior of the Born-scattering cross-section in higher dimensions.

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P5-10. Quantum Description of Unstable Behaviour of Intracavity Third Harmonic Generation Process

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[2]Institute for Physical Research, NAS of Armenia, Armenia

We study the quantum dynamics of the number of photons of the interacting modes, the dynamics of the quantum entropy, as well as the Wigner function of the states of the fundamental and the third harmonic modes for the process of intracavity third harmonic generation.

It is shown that the quantum dynamics of the system strongly depends on the external resonant perturbation of the fundamental mode and on the coupling coefficient of the interacting modes.

In the region of long interaction times, the modes of the field can be both in stable and in unstable states — depending on the above mentioned quantities. We also investigate the dynamics of transition of the system from stable to unstable state. It is shown that the third harmonic mode can localize in different unstable states with strongly different Wigner functions — depending on the coupling coefficient.

P6-1. Investigation of Exciton-LO-phonon Interaction in Semiconductor QDs

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In recent years quantum dots systems have been attracted much attention because of their advantages in optical and electrical properties. The optical properties of such devices are mostly affected by excitonic effects because of their small size. In this paper, the interaction between exciton, electron and LO phonon have been investigated in QD nanostructures. For this propose, we supposed an exciton which is confident perfectly in the spherical QD s with a radius of *R* and high frequency dielectric. The sphere is surrounded by the nonpolar matrix with dielectric constant of (E_d). To calculate the binding energy, the electron–LO phonon and the exciton–LO phonon coupling, the Hamiltonian for electron exciton and phonon are introduced, then with using the intermediate coupling and variational method the energy and wavefunction for as function of QD radius are obtained. The obtained results are emphases that the size dependence of these couplings plays important roles in optoelectrical properties. As shown in the figures with increasing the radius, the electron–LO phonon coupling becomes larger and the exciton–LO phonon coupling becomes smaller and eventually vanishes in the small dot. These results are examined for valid for most of the materials.

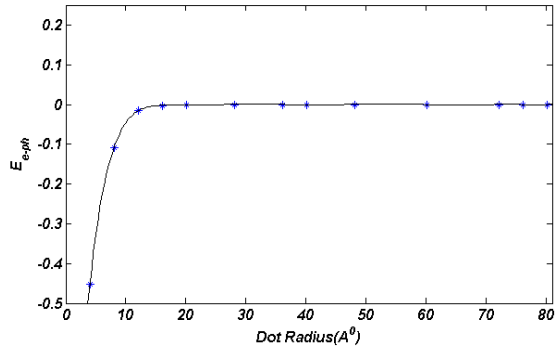

Fig. 1. The dot radius of exciton–LO phonon for GaAs.

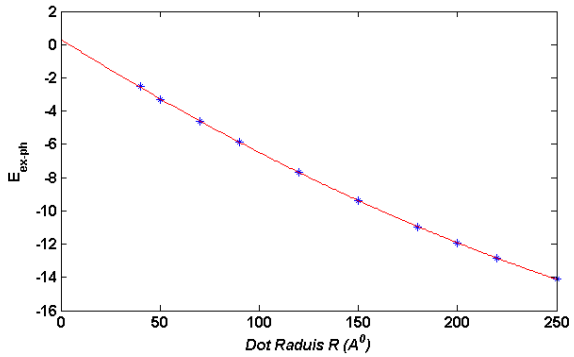

Fig. 2. The dot radius of electron–LO phonon for GaAs.

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P6-2. Determining the Nonlinear Coefficient of Gold and Silver Nanocolloids Using SPM and Z-scan

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Nonlinear and thermo optical properties of the gold and silver nanocolloids were investigated using CW Z-scan experiments. Sign of nonlinear refraction coefficient of colloids are negative at this condition. Negative sign implying thermal self-defocusing is the most important mechanism of nonlinearity in our experiments. Diffraction pattern shows that nonlinear refraction of gold nano colloid must be at least 3 times greater. The linear and nonlinear absorption coefficient of gold nano colloid and silver nano colloid is determined to be 0.9 cm^{-1}, 2.3×10^{-3} cm/W and 0.22 cm^{-1}, 1.9×10^{-4} cm/W respectively. These values produce temperature changes of about 90 K in gold nano colloid and 10 K in silver nano colloid at focus. Thermo-optical constants of samples are determined at low and high temperature changes at focus.

P6-3. Low temperature Study of an Organic/inorganic Complex Based on $PbBr_2$

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In this paper the luminescent functional crystal was produced by the organic guest molecule intercalation in the inorganic host crystal matrix. Firstly inorganic host/organic guest hybrid crystals were successfully prepared. Bands to band absorption peak at 352 nm, as well as a strong green photoluminescence emission at 532 nm were observed at room temperature. The luminescence spectra obtained from photoluminescence measurement at temperatures from 10k to 285k with 5k steps were investigated. The organic/inorganic hybrid powder was excited by 364 nm UV radiation. The emission intensities of fluorescence spectrum were significantly different at different temperatures and decreased by increasing the temperature. By decreasing the temperature of sample from room temperature to 11k, the position of photoluminescence peak wavelength showed a blue shift about 20 nm. Our spectroscopic investigations showed the hybrid has two different emission in blue and green area depends on excitation wavelength.

Р6-4. Прямое межзонное поглощение света в сферической квантовой точке с ограничивающим модифицированным потенциалом Пешля-Теллера

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Исследованы энергетические уровни и прямое межзонное поглощение света в сферической квантовой точке с ограничивающим модифицированным потенциалом Пешля-Теллера. Получены аналитические выражения для энергетического спектра частицы и граничные частоты поглощения. Выявлены правила отборов для квантовых переходов.

P6-5. Absorption Threshold Frequencies and Stark Shift in Narrow Gap InSb Spherical Quantum Layer

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The experimental realization of layered and ring-like semiconductor nanostructures makes it possible to consider a range of solid state quantum mechanical problems in which electronic, optical, and other characteristics of such systems are observed [1,2].

In the present work the electronic states, absorption threshold frequencies and the Stark shift in narrow band InSb spherical nanolayer are considered in the framework of Kane's dispersion low.

The electron and light hole dispersion law in narrowband InSb nanolayer is considered in the two-band approximation model [3,4]:

$$E = \sqrt{p^2 s^4 - m^2 s^4} - ms^2 , \tag{1}$$

where s is the parameter of non-parabolicity ($s \sim 10^{-8} cm/s$), m is the effective mass of the electron in InSb ($m = 0.015 m_0$). For the model of infinitely high potential barriers the wave function and the energy spectrum are defined from the equation:

$$(p^2 s^2 + m^2 s^4)\psi = (E - ms^2)^2 \psi \tag{2}$$

with the boundary conditions

$$\psi(R_1, \vartheta, \varphi) = \psi(R_2, \vartheta, \varphi) = 0 , \tag{3}$$

where $R_{1(2)}$ is the inner (outer radius) of SQL.

In the presence of external electric field and when the radial quantization degree is much more than the angular one the only coupling between the states 1*s* and 1*p* may be taken into account and the following expression for the energy levels is obtained [4]:

$$\mathbf{E}_{1s(1p)} = \frac{E_{1s} + E_{1p}}{2} - (+)\frac{1}{2}\sqrt{(E_{1s} - E_{1p})^2 + 4|H'_{1s1p}|^2} , \tag{5}$$

where

$$|H'_{1s1p}|^2 = \frac{(Fe)^2}{3}\left(\int_{R_1}^{R_2} f_{1s}(r) f_{1p}(r) r^3 dr\right)^2 \tag{6}$$

is the square of the matrix element between two states, $E_{1s(1p)}$ and $f_{1s(1p)}(r)$ are the energy and the radial wave function of the first (second) state in the absence of electric field.

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P6-6. Optical Sensitivity of Noble Metal Nanorods

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Position of the surface plasmon (SP) resonance in the metal nanoparticles depends on the geometry of the particles as well as on refractive index of immediate environment. In this respect the noble metal nanorods are of special interest since they exhibit sharp dependence of the SP frequency on aspect ratio. This circumstance turns out to be important, since a small change of refractive index of the surrounding caused by presence of e.g. biomolecules in the vicinity of nanorod leads to a significant shift of the resonance longitudinal frequency.

Recently we have introduced an approximate analytical method for calculating longitudinal SP frequency of nanorod as a function of aspect ratio, refractive index of environment and the dielectric function of bulk metal [1]. In this communication we further develop this theory in order to provide a method for determining the optimal aspect ratios of nanorods for application in biosensorics. The method is based on the calculation of sensitivity of the SP frequency in response to changes in the refractive index of the surrounding allowing to determine the optimal value of the aspect ratio for the given metal. We performed numerical calculations based on the discrete dipole approximation that did not show any noticeable deviation from our analytical results.

Obtained formula demonstrates excellent agreement with the results of numerical calculations with use of the boundary element method [2] and confirms the idea of using nanorods as sensors in one-molecule biophysics.

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P6-7. Electric Field Tuning of the Band Gap in Four Layers of Graphene with Different Stacking Order

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Graphene is a two-dimensional (2D) crystal of carbon atoms packed into a hexagonal lattice with a *k*-linear Dirac-like spectrum of charge carriers. The fabrication of single and multilayers of graphene stimulated the investigation of the electronic, optical, and transport properties of such graphene systems [1].

A serious draw-back of the use of a single layer of graphene for electronics is the observation of gapless nature of the graphene spectrum. Theoretical and experimental investigations have shown that this difficulty can be overcome by using a perpendicular electric field applied to bilayer graphene [2]. This allows the opened energy gap between the valence and conduction bands to be tuned from zero to midinfrared energies. Electrical tunable energy gap systems are of interest not only from a fundamental point of view, but also for possible applications in electronics (e.g., for transistors) and photonics (i.e., wavelength tuning of a laser or on optical detector).

Recently, we investigated three as well as four layer graphene systems in the field of top and back gates which allows to control *independently* the density of electrons on the graphene layers and the Fermi energy of the system [3].

Multilayers of graphene can be stacked differently depending on the horizontal shift between consecutive graphene planes, leading to very different electronic and optical properties. The Bernal stacking (*ABA*), which has hexagonal symmetry, is common and stable, but some parts of graphite can also have rhombohedral stacking (the *ABC*). In [4] we studied electric field induced band gap of multilayers of graphene with different ways of stacking. We found that the gap for trilayer graphene with the *ABC* stacking is much larger than the one for the *ABA* stacking. Similarly for four layers of graphene the energy gap also strongly depends on the choice of stacking and is smallest in case of Bernal stacking.

In the present paper we extend our earlier investigations and study the band structure of four layer graphene systems with *ABBA*, *ABCB* and *ABAA* stackings in the presence of top and back gates.

We found that a large gap (about 100 meV) can be opened in the *ABBA* and *ABCC* systems by tuning of the gate potentials. In contrast, we obtained that multilayer graphene which contains a trilayer with the *ABA* Bernal stacking does not exhibit any opening of an energy gap.

We use a tight-binding approach within a self-consistent Hartree approximation to calculate the induced charges on the different graphene layers.

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P6-8. Optical Properties of a Shallow Donor near Semiconductor-metal Interface

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The investigation of the energetics of dopant atoms in nanoscale devices and near different interfaces is a very important topic of research in recent years. Dopant atoms provide free carriers in the conduction band or the valence band, respectively. Therefore the binding energy is of crucial importance to characterize a dopant atom. In order to measure the binding energy of dopants as a function of the device dimensions [1–3] experimental efforts have been taken.

On the other hand, today dopant atoms could be used as the functional part of a device instead of just providing charges. An example is the proposal of Kane [4] to use donor states as qubits. Due to further miniaturization of semiconductor devices the dopant atoms appear closer and closer to interfaces and correspondingly the study of such impurity states becomes a problem of fundamental interest.

The energy spectrum of a donor located near a plane semiconductor/metal interface was investigated in Ref. [5] using the finite element technique. In our previous work [6] we investigated the lowest electronic states of a donor located near a semiconductor-insulator-metal plane interface within the effective mass approximation. The lowest energy states were obtained using a variational approach, which takes into account the influence of all image charges that arise due to the presence of the metallic and the dielectric interfaces. The results were compared with a numerical exact calculation using the finite element technique and a good agreement was obtained.

The investigation of optical properties of shallow donor near different interfaces is of great interest. In this work on the basis of the results obtained in [6] we study the intraband light absorption between lowest energy states of a shallow donor near semiconductor-metal interface.

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P6-9. The Influence of the Spin-orbit Interaction on the Moving Polaron in a Semiconductor Nanostructure in Electric and Magnetic Fields

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In this paper, the Lee-Low-Pines unitary transformation method was used to study the properties of the moving polaron considering the influence of Rashba effect, which is brought by the spin–orbit interaction, in the semiconductor nanostructure in the presence of electric and magnetic fields. Numerical calculation on the GaAs, as an example, is performed. The expressions for the self-energy and the effective mass of the polaron as a function of the vibration frequency, the velocity, the coupling constant and the electron density were derived. Numerical results show that the total effective mass of the polaron is composed of two parts, one part is caused by the Rashba effect and the second term is induced by the electron and LO phonon interaction.

P6-10. The Effect of Screened Coulomb Interaction on the Optical Properties of EuS/PbS/EuS Finite Confining Quantum Well

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The model to investigate of optical properties of realistic EuS/PbS/EuS finite confining potential quantum well (QW) systems in presence of quasi-two-dimensional (Q2D) electron gas (EG) developed theoretically [1].

A variational approach for the study of influence of exciton effects on the interband absorption spectra of lead salt QW system in presence of Q2DEG has been implemented. A strong contrast of available material parameters across the QW interfaces and characteristic band-nonparabolicity effect of lead salt semiconductor are taken into account. An appropriate Q2D statically screened long-wavelength potential function [2]

$$V_S(\rho) = -\frac{2e^2}{\varepsilon_w d} K_0\left(\sqrt{\frac{2q_S}{d}}\,\rho\right)$$

has been used in first time, where K_0 is the modified Bessel function of the second kind, $\rho(x,y)$ is an in-plane 2D distance between the charges, ε_w is the QW material static dielectric constant, q_S is the 2D screening parameter and q is the 2D in-plane wave vector, d is the QW width.

By using the-cut-off Coulomb potential method [3,4] the analytical expression for the factor S determining the contribution of exciton effects to the optical absorption are obtained. It is shown, that screened exciton factor oscillates spatially depending from the screening length. A firm dependence of from QW width makes exciton factor strongly enhanced for the thin enough QW's, thus indicating the necessity of taking into account the screening in optical absorption.

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P6-11. The Optical Properties of Pulsed Laser Deposited Amorphous Ge Films

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Amorphous Ge films (thickness 25–450 nm) were obtained on the glass substrates at room temperature by the vacuum ($3 \cdot 10^{-6}$ mm Hg) pulsed laser (Q-switched glass:Nd^{3+} laser: wavelength — 1.06 μm, pulse duration — 30 ns, intensity in the Ge target irradiation zone — ~10^9 W/cm^2) deposition method in a non-equilibrium conditions of growth. The optical properties of fabricated films were studied in the range of 400–1000 nm using a spectrometer Filmetrics F20. It is shown that the optical properties of the films explained by Tauc model for amorphous semiconductors. It was also established that the band gap of films depends on the thickness.

P6-12. Raman Spectra and Structural Transformations in Nickel-Carbon Nanocomposites

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Magnetic Ni_x/C nanocomposites with $0 < x < 0.03$ have been synthesized by solid-phase pyrolysis of phthalocyanines. Structure, composition and magnetic properties of prepared samples were investigated by scanning electron microscopy, X-ray diffraction, electron magnetic resonance and Raman spectroscopy. It is shown that in Ni_x/C nanocomposites at $x \approx 0.01$ a structural transformation occurs which leads to essential changes in X-ray diffraction, Raman spectra and electron spin resonances.

P6-13. Influence of Color Centers on Spectral Properties of Ce^{3+} Ions in YAG:Ce Crystals

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Influence of color centers on spectral properties of Ce^{3+} ions in Ce-activated single crystals of yttrium-aluminum garnet is studied. Interactions between color centers and Ce^{3+} ions have been considered taking into account the effects induced by γ-irradiation. Existence of displaced positions of Ce^{3+} ions in the crystal lattice is shown. The observed changes of the luminescence band wavelength of Ce^{3+} ions ($4f^05d^1 \rightarrow 4f^15d^0$ transition) are discussed with account of the spectrum taken on a ceramic sample.

The work is carried out in the frame of the IRMAS research programs and in the frame of the Crystal Clear collaboration.

P6-14. Comparison of Optical Properties of LuAG:Pr and LuAG:Pr(Sc,Hf) Scintillation Crystals Grown by the Bridgman Method

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$Lu_3Al_5O_{12}$:Pr (LuAG:Pr) is reported as a prospective scintillator with a fast decay time (~20 ns) and high light yield due to the 5d–4f radiative transition of Pr^{3+} ion [1]. Czochralski [1] and micro-pulling [2] techniques were applied to this material. The currently reported light yield values are 18000–19000 ph/MeV. The objective of the present work was to apply to this and to a few modified crystal compositions (LuAG:Hf, LuAG:Pr,Hf and LuAG:Sc,Pr) the vertical Bridgman method and to evaluate their properties. Broadening and shift of absorption bands at 240 nm and 280 nm associated with 4f–5d transition of Pr^{3+} ion have been observed in LuAG:Sc,Pr, in comparison to LuAG:Pr, resulting from lower crystal field and some lattice disorder introduced by Sc^{3+}. The measurements were done on thin (0.1 mm) plates with a similar Pr^{3+} content which was controlled using the obtained dependences of absorption coefficients at 240 and 280 nm on Pr^{3+} concentration. Introduction of Sc^{3+} increases the segregation coefficient of Pr^{3+} from 0.065 [1] to 0.087 (for Sc = 10%) and is useful for preparation of concentrated samples. Addition of Hf^{4+} resulted in improvement of the transmission in the UV range including the range of emission, so that smaller re-absorption losses can be provided. The light yield measured in LuAG:Pr(0.2 at%)Hf(30 ppm) is ~20600 ph/MeV (8.2 μs gate). The fast decay component is weakly dependent on both Pr^{3+} (0.2–0.9 at%) and Hf^{4+} (0–45 ppm) concentrations and is about 20 ns.

The work is conducted in the frame of Crystal Clear collaboration and in the scope of IRMAS and Project 1-6/2 of Ministry of Science of Armenia.

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