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Problems of Interaction of Radiation with Matter

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Book of Abstracts

Igor V. Semchenko, Sergei A. Khakhomov (editors)

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Gomel State University
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B.I. Stepanov Institute of Physics of National Academy of Sciences of Belarus
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Problems of Interaction of Radiation with Matter is an international conference that focuses on the following fields

A. Nonlinear optics and optics of crystals

B. Laser physics and laser technology

C. Electromagnetic theory

D. Acoustooptics

The Conference is devoted to the 75th anniversary of B.V. Bokut', of the former rector of the Gomel State University.

This meeting will be held at the Gomel State University (Gomel, Belarus) during 30 October–1 November 2001. The present report is the collection of abstracts of contributions that have been accepted and invited to be presented at the meeting. After the meeting, full proceedings will be published.

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Boris Vasilyevich Bokut' (27.10.1926–15.3.1993) is a well-known theoretical and experimental physicist, Academician of the Academy of Sciences of the BSSR (1980), Doctor of Physical and Mathematical Sciences (1973), Professor (1975). Boris Vasilyevich graduated from the Byelorussian State University in 1952. From 1955 he was a researcher, from 1970 he was the Head of the laboratory of crystal optics at the Institute of Physics, the Academy of Sciences of the BSSR. He was the Rector of the Gomel State University named after Frantsisk Skorina (1973–1989), senior researcher of the laboratory of crystal optics at the Institute of Physics, the Academy of Sciences of Belarus (1989–1991), adviser of Director of the Institute of Physics, the Academy of Sciences of Belarus (1991–1993).

His scientific investigations were devoted to the problems of theoretical crystal optics. He has developed some methods that help to solve boundary problems in electrodynamics of chiral crystals and the methods of the determination of all parameters of chirality by measurement of polarization of the reflected and refracted waves.

He revealed the main aspects of the phenomenon of nonlinear chirality, nonlinear frequency transformation of radiation, he studied a nonlinear ponderomotive effect of high-power radiation on crystals.

He is a prize-winner of The State Premium of the USSR in the field of effective transformation of radiation frequency of lasers (1984). He is the author of about 200 scientific works, including 3 monographies and 20 inventions.

Igor V. Semchenko, Sergei A. Khakhomov

Section A
Nonlinear optics and optics of crystals

Nonlinear crystal optics of Bessel light beams

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The regime of azimuthally matched interaction of Bessel light beams (BLBs) is investigated, which was realized when the azimuthal phase mathching width is small. It is shown that in proceces of these interactions the correlation of the azimuthal BLB components is induced. It is found that a nonlinear polarization field, formed by azimuthally correlated BLBs, is also a Bessel beam and is not a quadratic combination of the Besselfunction, as is true for the uncorrelated beams. The overlap integral then assumes its maximum value becase of the identity of the spatial structures of the polarization and the field generated by the polarization.

Parametric generation of light by pumping with Bessel light beams has been investigated. A theory of azimuth - mathced thee-wave parametric interaction of Bessel light beams has been developed. It is shown that at such an interaction in the parametric generator the coupling coefficient reaches its maximum and no destruction of the spatial structure of intracavity fields at high coefficients of conversion occurs. This opens up the possibility of increasing the energy conversion from an input Bessel beam compared to that of a Gaussian beam. It is established that the Bessel beam is, in a statistical sense, the azimuth average of the plane wave equal-probable distributed at the cone surface.

To the theory of ultrashort spatiotemporal solitons

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3+1-dimension optical spatial-temporal solitons called light bullets can be formed in nonlinear media under the influence of the powerful ultrashort laser pulses. There is no analitical description for such solitons. Dinamics of their formation and their properties are determined by numerical solution of suitable nonlinear equations. When numerically simulating light bullets properties we consider that Kerr local nonlinearity is just the most suitable one for the description of the almost instant interaction of the light bullet with the media. Other nonlinearities have finite time of the response and can not determine peculiarities of squeezed in space and time light bullets. It is known that in Kerr nonlinear media only 1-dimension solitons are stable. Nevertheless soliton squeezing process takes finite time. Collapse time estimation shows that because light bullet is the ultrashort pulse there is just no enaugh time for the soliton collapse to occur. It is well-known that spatial solitons have bell-like shape. Proceeding from this fact we have tried to use Gaussin's functions when analysing light bullets properties. It is shown that in general case light bullet exists in the form of the pulse oscillating in space and time.

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New representative of waves in chiral crystals

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On the basis of the theory of continous groups of transformations a new representation of waves in chiral crystals is developed [1]. It is shown that at the absence of a conductivity current after introduction instead of impermittivities their square roots the Maxwell equations lead to unitary relations and directly determine Hermite operator (generator) of continous transformations. In the special case of simple harmonic plane waves this operator represents a velocities tensor in the form of a convolution of a wave vector with the 3-th rank tensor of optical constants which determine principal velocities of waves in crystal. This Hermite velocities tensor is planar, without trace, dual to a complex vector of ray (group) velocities and similar to an angular momentum tensor. It directly determines group velocities of isonormal waves in the chiral crystal. The obtained expressions of the ray velocity vectors are linearly dependent on the direction of a wave normal and are very simple as in nonchiral crystals. Phase velocities and polarization vectors are determined as projections of the ray velocity vectors on a normal and on an orthogonal normal plane respectively. It is established that a chirality represents a particular form of an anisotropy, which is stipulated by a spin and apparent in an elliptic or circular polarization of waves. This anisotropy implies a phase indefiniteness of the velocities and a discrete quantum nature of a change of an invariant of the velocities tensor.

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Optical properties of chiral crystals with structure Ca-gallogermanate

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The complex research of optical properties of crystals with structure Ca - gallogermanate is performed. The following crystals were investigated: $La_3Ga_5SiO_{14}$, $La_3Ga_5GeO_{14}$, $La_3Ga_{5,5}Nb_{0.5}O_{14}$, $La_3Ga_{5.5}Ta_{0.5}O_{14}$, $Ca_3Ga_2Ge_4O_{14}$, $Sr_3Ga_2Ge_4O_{14}$. Spectroscopic properties of crystals $Ca_3Ga_2Ge_4O_{14}$ and $Sr_3Ga_2Ge_4O_{14}$, doped by ions of chromium, and also crystals $La_3Ga_5SiO_{14}$ doped by ions of chromium, manganese and nickel are investigated. All undoped crystals have bands of absorption and have noticeable linear dichroism in short-range ultra-violet and visible areas of a spectrum. All crystals are transparent in short infrared range of spectrum. Almost all crystals have areas of an abnormal birefringence, which corresponds to bands of dichroism. It is shown that for a given class of crystals it is possible to use a principle of additivity to calculate molecular refraction and to estimate refractive indexes of new crystals of such type. Components of gyration pseudotensor practically coincide in transparent and doped crystals. Component g_{11} has the positive sign and g_{33} has negative sign for right-handed crystals. The absorption spectra and circular dichroism of all doped crystals are investigated. In absorption spectra of doped crystals the bands related to ions Cr^{3+} and Cr^{4+} in octahedral coordination and tetrahedral coordination accordingly and ions Mn^{2+} and Ni^{2+} in octahedral coordination are found. In circular dichroism spectra of crystals the bands related to doped ions are found and the additional ones, which are not connected with doped ions. Probably these additional bands in circular dichroism spectra in all crystals are related to defects generated during crystal growth.

Acknowledgement

All investigated crystals are grown by B.V. Mill at the Moscow State University. The authors are very grateful for him.

The electric and magnetic modification of the chirality of the ε-isotropic crystals

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The phenomenological theory of the effect of an external electric and magnetic field on the light wave propagation in tetragonal chiral crystals with crossed dispersion curves of the main values of the permittivity tensor is advanced. The theory is based on the Onsager - Casimir principle in the following formulation:

$$\tilde{K}(\mathbf{e},\mathbf{h}) = TK(\mathbf{e},-\mathbf{h})T^{-1}$$

Here

$$K(\mathbf{e},\mathbf{h}) = \begin{pmatrix} \varepsilon(\mathbf{e},\mathbf{h}) & \alpha(\mathbf{e},\mathbf{h}) \\ b(\mathbf{e},\mathbf{h}) & \mu(\mathbf{e},\mathbf{h}) \end{pmatrix}$$

is the 6×6-matrix of constants in constitutive equations

$$\mathbf{D} = \varepsilon\mathbf{E} + \alpha\mathbf{H}, \quad \mathbf{B} = b\mathbf{E} + \mu\mathbf{H}$$

of electrodynamics of bi-anisotropic media, $\mathbf{e}$ and $\mathbf{h}$ are the vectors of external electric and magnetic fields respectively,

$$T = T^{-1} = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$$

is the 6×6 -matrix of time inversion for electromagnetic field.

Effect of photoelasticity in the holography of photorefractive crystals. A review

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For the first time the photoelasticity and piezoelectricity phenomena in the photorefractive crystals holography was considered in [1]. In this paper the influence of these phenomena on the orientation dependence of the diffraction efficiency in $LiNbO_3$ was studied. Then the development of this theory for the case of the cubic photorefractive chiral piezocrystals of sillenite-type was realized. Analytical solutions of the equations of coupled waves for these crystals were obtained. Experimental investigations confirming the general conclusions of the theory were performed.

The ways of optimization of the output characteristics of holograms in a cubic photorefractive piezocrystal were suggested. The orientation and thickness dependencies of the maximal gain at two-wave mixing and the maximum diffraction efficiency of hologram were derived for the first time.

The microscopic model of Kukhtarev and others for description of the diffraction process and the model of shallow traps were used. The photo-induced absorption has been into account while the reflected holograms in the cubic piezocrystals were studied. Two-wave mixing and diffraction in the cubic piezocrystals under AC electric field was examined too.

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Two-beam coupling on reflection holographic gratings in $Bi_{12}TiO_{20}$ crystals

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The reflection gratings in photorefractive crystals are of great interest for real-time dynamic holographic interferometry [1] and optical filtration. We report the two-beam interaction for counter-propagating geometry in $Bi_{12}TiO_{20}$ crystals with light- induced absorption. We derive the coupled-wave equations taking into account the light absorption and the vector nature of interacting waves in a chiral cubic crystal. The exact solution for this set of equation in undepleted pump beam approximation is obtained. It is shown that any interaction is absent in the case of (110) cut of a crystal. In a sample with the (111) orientation the gain coefficient is independent of polarization state of interacting waves if they polarization are the same on the entrance face for a signal beam. In the (100) cut of a crystal the waves with circular polarization can be coupled through nonunidirectional effect only. The crystals were grown by modified Czochralsky technique. In our experiments we have used the samples with the (110), (100) and (111) orientations. It is known that a strong light-induced absorption is typical for $Bi_{12}TiO_{20}$ crystals.

Because of this, the samples were placed in an opaque box opened exclusively during an experiment. A volume holographic grating was formed inside the crystal in response to interference pattern between the incident beam and the beam reflected from the exit face of a sample. Time evolution of both two-beam coupling on reflection grating and light-induced absorption which start simultaneously after the illumination of a crystal by light with wavelength of 633 nm is experimentally investigated. We have observed the growth of a grating during a period of ~ 1 h with its subsequent decreasing for light intensity of $\sim 150 mW/cm^2$. A peak exponential gain coefficient has the dependence on the pump intensity. The peak magnitude of the gain attainable in the (100) cut for some samples was estimated as $\Gamma = 4.7 cm^{-1}$. The additional light-induced absorption riches the value of $\Delta\alpha \sim 0.8 cm^{-1}$. The dark decay of a created reflection grating in the investigated samples continued for several days.

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Refraction peculiarities in the binary systems of rare-earth element and strontium fluorides

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The results of the refraction study of two-component solid solution single crystals grown on the basis of rare-earth element (REE) fluorides with different content of strontium fluoride ($R_{1-x}M_xF_{3-x}$, where R = La, Ce, Pr, Nd; M = Sr; $0 \leq x \leq 0.15$) are presented.

Experimentally obtained values of refractive indices and density have given the possibility to calculate some refractometrical characteristics of the crystals investigated: molar (Lorenz-Lorentz) and specific (Newton) refraction, polarizability, molar volume.

All the data obtained were analyzed in two directions:
1) with the increase of SrF_2 content x for each binary system;
2) according to REE atomic number for one and the same x.

It was revealed that the refractive index decrease, depending on the SrF_2 content, relates to the decrease of molecular polarizability with x increase. Whereas the more complex character of refractive index variation in the crystals with different REE is explained by two competing factors: namely, the polarizability decrease and the growth of the number of molecules in unit volume with REE atomic number increase.

Mechanism of formation of optical anisotropic nonlinear waveguides in polycarbonate

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The results of study of optical parameters of anisotropic layers formed in a polycarbonate substrate when producing optical waveguides with nonlinear properties by the method of chemical diffusion from a saturated solution of the azo-dye Methyl Red are presented. The optical properties of layers obtained are shown to be appreciably stipulated by interaction between the solvent and the polymeric matrix enhancing an increase in the polymer molecule orientation degree of the surface layer. As a result, the latter acquires properties of an uniaxial crystal whose optical axis is perpendicular to the surface of the substrate. By comparing optical parameters of layers formed by diffusion of the dye-containing solvent and the pure one, a contribution of the orientation phenomenon to the change in the refractive index is evaluated and a model of formation of waveguides in polycarbonate by the diffusion method is proposed. The features of

refractive index profiles of these layers for TE- and TM-polarizations of the probing light and their possible applications in integrated-optics polarizing devices are considered.

Features of Bessel light beam self-diffraction

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For the first time some features of self-diffraction of Bessel light beams (BLB) having the cone base angle of 1 deg were investigated. As a nonlinear medium the Rhodamine 6G dye layer with the thickness of 0.1 mm was used. The diffracted BLB is shown in the Figure 1.

External and bright internal rings correspond to the first and the zeroth order of diffraction respectively. The first order diffraction ring is bifurcated, and the diversity angle increases when the conicity angle of initial BLB decreases. For the first time diffraction rings inside the ring of the zeroth order were registered. These rings arise apparently as a result of faultiness of the axicon forming the initial BLB. The difference between the real axicon shape and the ideal cone surface nearby the cone

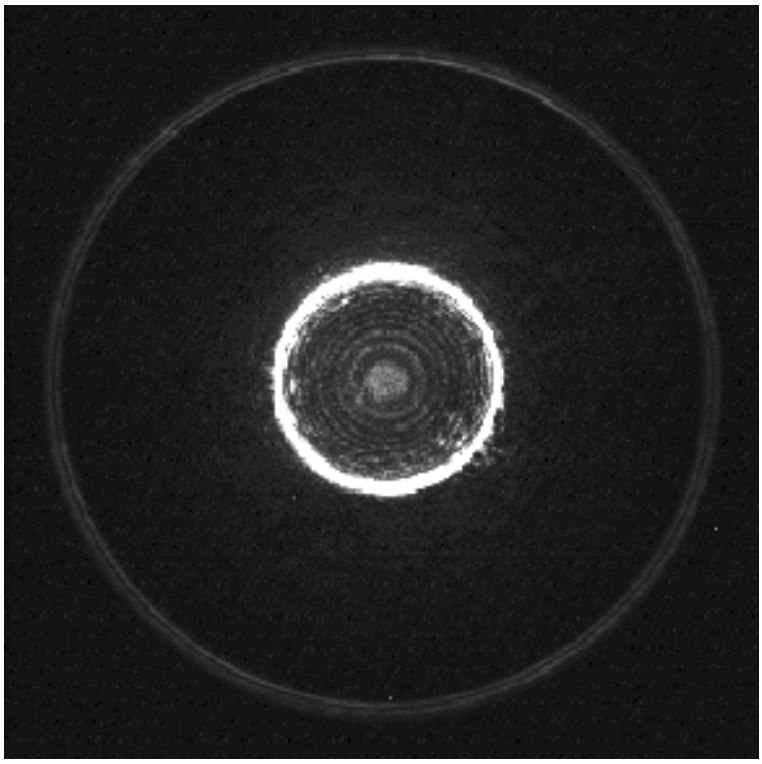

Figure 1. Bessel light beam self-diffraction pattern.

vertex results in radial intensity oscillation of initial BLB. The stronger these oscillations are, the more intensive are rings inside the brigt zeroth order ring. The number of rings inside the bright ring depends on the distance between the axicon and the nonlinear layer. As this distance increases, the number of rings increases also, and both the maximum and minimum of intensity can be observed in the center of the self-diffraction pattern.

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Photorefractive spatial solitons in planar optical waveguides: experimental observation and special features

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Photorefractive spatial solitons can arise in some electrooptic crystals at light powers of microwatt range. Optical waveguides can provide much higher photorefractive nonlinearity with respect to a host material and optical nonlinearity may strongly change over a waveguide depth. Besides, waveguides allow simultaneous propagation of several guided modes in the same direction. These features may result in the significant distinctions of spatial solitons in a waveguide configuration with respect to similar effects in bulk crystals. We experimentally studied the effects of formation of photorefractive spatial solitons at light wavelengths from the visible to near infrared in planar waveguides on a base of some electrooptic crystals like lithium niobate, strontium - barium niobate and barium - calcium titanate. Optical waveguides were formed in various crystals by indiffusion of photorefractive impurities like Fe and Cu or by ion - implantation method. The experimental results related to observation of bright and dark photorefractive spatial solitons in such waveguides will be discussed in this paper.

Effect of external electric field sign on light wave polarization in $Bi_{12}TiO_{20}:V$ crystal

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Sillenite crystals $Bi_{12}SiO_{20}$ and $Bi_{12}TiO_{20}$ are the frequently used photorefractive materials. They belong to the 23 point symmetry group and possess, among the linear electrooptic effect, the natural chirality. The enhancement of the photorefractive response in the sillenites is usually achieved by applying an alternate external electric field of a square-wave form.

The conventional theoretical model taking into account the linear electroroptic effect and the chirality predicts an elliptical polarization for a light wave propagating inside the crystal. If the input wave is linearly polarized, a change of the sign of the polarization rotation at each point of the crystal without any changes in the polarization-ellipse inclination and ellipticity when switching applied field must be observed.

We report, nevertheless, on the experimental observation of the change in the polarization-ellipse inclination of light wave propagating in $Bi_{12}TiO_{20}$:V crystal with the sign of applied field. It is shown that theoretical models taking into account effect of electroabsorption or internal elastic strians in the crystal can explain the effect of external field sign

on light polarizaion. For the investigated sample of the $Bi_{12}TiO_{20}$ crystal we have a good agreement of the experimental results with the theory taking into account the internal elastic deformations of the sample. The absolute value of the deformations was also measured in our experiments.

Planar ring shift register for digital systems of optical information processing

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Transverse effects in optical bistability can be used for developing novel architecture designs of digital systems for optical computing and processing. In particular, the design, principles of operation and experimental realization of all-optical planar ring shift register based on the nonlinear thin-film semiconductor interferometer are represented. Bistable pixels forming this ring shift register are capable of performing logical operations and can exchange the information stored by transporting the information signal over the ring planar circuit by means of switching waves in the plane of bistable interferometer, the direction of information transport being normal to the direction of propagation of holding and signal beams. Input and output of information can be accomplished in all the elements of a ring shift register.

The system under consideration can be used for development and construction of memory devices and optical systems for digital information processing, transfer and spatial switching of light information signals.

The simplest planar ring shift register of 6 pixels has been experimentally realized with the use of thin-film ZnS–interferometer prepared by vacuum deposition technique.

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Dynamic balance of lattices of a charge in photorefractive crystals

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The correct expression for distribution of charge lattices in photorefractive crystal with a standing light wave oriented in a direction by one from crystalline axeses is found. It is established, that the usually considered picture of currents in a lattice which is taking into account a diffusion and a drift of carriers only along this axes, is incomplete and should include as well drift currents existing in perpendicular planes. We formulate the condition of a dynamic balance of a lattice in a stationary condition, which concluded is equality of absolute values of a velocity of damping of a charge, caused by full drift current, and velocity of generation of a charge caused by diffusion. It is shown, that the presence of transversal currents results in essential lowering of stationary magnitude of a charge, and in case of an isotropic medium the real amplitude of a density of a lattice charge appears three times below by what follows from an one-dimensional approximation. The effect of deformation of lattice of a charge practically absent on minor (small) depth of modulation of light and growing with increase of a modulation factor is theoretically detected also.

Bessel light beams in uniaxial crystals

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We present the results of our investigations of properties of nonparaxial Bessel beams of zero and higher orders in anisotropic media. These investigations are promising for solution of many problems of nonlinear optics and in theory of interaction of optical fields with atomic systems. We found the exact solutions of Maxwell equations which correspond to ordinary (o) and extraordinary (e) plane waves. The vector of electric field strength of o-type Bessel beam, like ordinary plane wave, has nonzero φ-component. Besides, this vector contains the circularly polarized component, which is non-zero only for Bessel beams of higher orders. The components of Pointing vector of o- and e-type Bessel beams are calculated. The energy flows of Bessel beams are of spiral form, which takes place for higher-order Bessel beams only. The dependence between the orientation of angular momentum of the beam and its polarization state is established. The change of direction of circular polarization of the beam or its spin momentum causes the change of direction of its angular momentum. This means the manifestation of spin-orbit interaction inside the Bessel light beam.

Effects of a light leakage in planar optical waveguides

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Leaky optical waves can exist in planar optical waveguides on a base as of optically anisotropic materials as isotropic multi-layer structures. An effect of a light leakage brings the additional loss to the guided light, but on the other hand it can be used for the direct excitation of guided modes by light beams within a substrate without any coupling elements. We studied theoretically and experimentally some features of a light leakage effect in planar waveguides which can be formed in electrooptic crystals either by metal diffusion or proton exchange or ion implantation. The characteristics of leaky waves in multi-layer waveguide structures

modeling the planar waveguides formed in various materials by the ion implantation method were inspected theoretically. We considered the models of a step - like as well as the gradient waveguide layers separated from a substrate by a barrier layer with decreased refractive index. The optical losses resulted from the light leakage in such waveguides were estimated and compared with known data for some real structures. For the optically anisotropic waveguides we have obtained a set of equations for the light fields in a planar waveguide with arbitrary refractive index profile. From these equations we analysed the propagation of light along the crytallographic axis within a waveguide with step - like change of the permittivity. We considered all components of the real dielectric tensor as nonzero in this case. The dispersion equation has been obtained for such a structure and some its solutions have been analysed. This analysis allowed for the estimation of a light decay on the nondiagonal component value of the dielectric tensor in planar proton - exchanged waveguides on lithium niobate.

Production and transformation of non-Bessel multi-ring light beams

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Method of formation of non-Bessel multi-ring light beams (MRLBs) on the base of biaxial crystal was investigated. The method has been optimized using diverging lens for transformation of powerful input laser beams. Intensity distribution in the output MRLB has been studied experimentally in dependence on the divergence and intensity distribution of the input light beam. It has been shown, that the larger is input beam divergence the more rings are there in the output MRLB. The envelope of intensity maxima of the radial intensity distribution in the output beam corresponds to the radial intensity distribution in the output beam.

It has been found out that the different crystals can provide the different period of a function modulating radial distribution of intensity in MRLB. Transformation of obtained MRLB by the same method with the second crystal placed in series was carried out. Multiplication of the modulating functions occurs, when the noncoincidence of the modulation periods in a two different crystals takes place. Wave front dislocations behavior during these transformations was investigated.

Second harmonic generation in the KTP crystal with a beam having two ring was investigated in detail. The parameters of optical scheme for doubling of the number of ring in the beam have been determined. It has been found out that the transformation of the wave front dislocation is influenced by the degree of a MRLB focusing in a nonlinear crystal.

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Standing Bessel light wave

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Method of a standing Bessel wave production based on the use of two conical surfaces is proposed. The optical scheme of the method is shown in Figure 1.

The sufficiently powerful Bessel light beam (BLB) exists in the region which approximately corresponds to the figure formed by rotating the shaded rhomb and has finite dimensions. The maximum distance from axicon, where the BLB still exists, is $z_B=R_d/\gamma$, where R_d is the radius of the diaphragm limiting the collimated coherent light beam illuminating the axicon. The angle γ is the conicity angle of the BLB produced by the axicon ($\gamma=\arcsin(n\sin\alpha)-\alpha$, where n and α are the refraction coefficient and cone base angle of the axicon). A reflective concave conical surface with angle γ forms the standing Bessel wave (Fig. 2(a)).

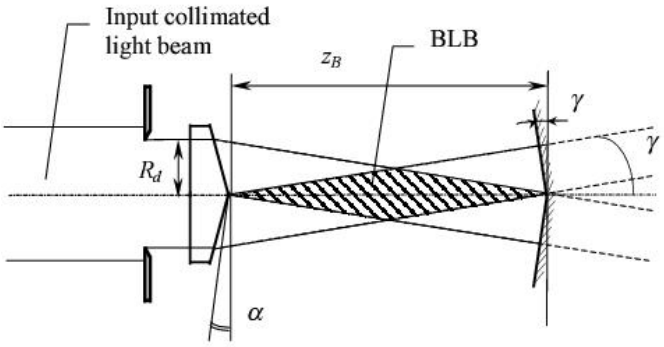

Figure 1. Optical scheme for standing wave production

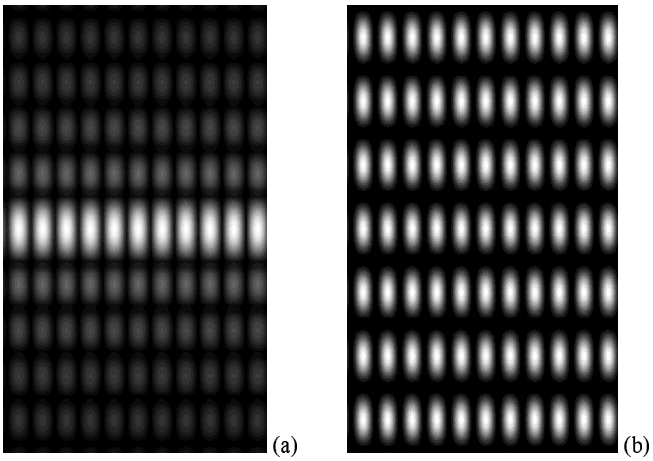

Figure 2. Electromagnetic field distribution of (a) the standing Bessel wave, (b) the field formed in result of interference of two beams or four beams, shown in the plane of Figure 1

The conical surfaces can be replaced by the double prism (biprism) or by the pyramid surfaces with the angles corresponding to α and γ. These elements allow to produce standing waves with the intensity distribution shown in Fig. 2(b). The number of refracting planes determines the number of refracted light beams, which take part in production of the standing wave.

The proposed standing waves are the periodic gradient electromagnetic fields. They can be used for trapping and control of particles, production of dynamical gratings, and operation with organic cell and its components.

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Second harmonic generation by Bessel light beams in nonlinear crystals with small angular phase-matching width

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In this paper the features of the second harmonic generation (SHG) by Bessel light beams using the nonlinear BBO (β-BaB_2O_4) crystal are investigated theoretically and experimentally. The angular width of phase matching is 0.51 mrad for the crystal length of 5 mm. It is much less than the conicity angle of the fundamental-frequency Bessel beam. Therefore the SHG intensity distribution is the result of scanning of the angle range occupied with Bessel beam by the phase matching direction.

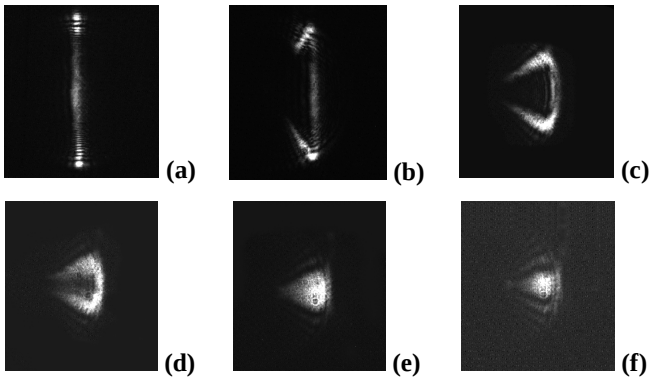

Figure 1. The second harmonic intensity distribution dependence on the phase matching detuning. The detuning angle is 0 (a), 0.1 (b), 0.2 (c), 0.3 (d), 0.4 (e) 0.5 (f) mrad.

Experimental intensity distributions for the different angles of phase matching detuning in the far-field are shown in Figure 1. One can see that fragments of the ring distribution which is typical for crystals having wide phase matching range appears by scanning.

Temporary features of diffraction characteristics of holograms in photopolymers

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Earlier we created mathematical model of dynamics of a record of the passing holograms in photopolymers and the technique of definition of its parameters on experimental data in area of small times is developed. We conducted experiments on a record of the holograms under different angles in photopolymers created in Institute of Organic Chemistry of Novosibirsk. The parameters of mathematical model were as a first approximation obtained in the field of small times and then they were generalized for case of large effectivenesses of diffraction (more than 50 %). The diagram of angular selectivity of the recorded holograms also were obtained. Through one year the hologram were investigated repeatedly, thus the following changes are remarked: the efficiency of diffraction, especially in samples recorded at small angles was increased (in 2-3 times). It is possible to explain it to that after a record we were not fixed the photopolymer sample and monomer was not expended completely. With the cource of time, owing to diffusion processes, there was an equalization of concentration a monomer as in the field of a record, so outside of it (amplification in dark). Then at repeated research of the holograms the effect of optical self-amplification was observed. It was accompanied by distortions of curve angular selectivity: by displacement of a maximum, formation of a bifurcated structure, by non-centra, increase of a pass-band, essential increase of levels of side-lobes. The obtained data testify to essential change is peak - phase structures of a recorded holographic grating owing to interference processes of the initial hologram with an additional record owing to optical self-amplification. The outcomes of research speak about a capability of increase of contrast of recorded images at a record of the complex holograms by directional processes of optical self- amplification.

Acoustically stimulated phase transition and low temperature optical spectra in PbI_2 crystal

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PbI_2 is a layered crystal and it consists of strongly bonded layers. Many polytypes of PbI_2 exist because of different possible orders of layers package. The aim of this work was to study the influence of ultrasonic wave on the PbI_2 structure. We studied the transformations of the simplest and the most stable 2H polytype after the exposure to the acoustical wave with frequency 2.25 MHz and the intensity about $1W/cm_2$. The direction of ultrasonic wave propagation was perpendicular to the crystal layers. A nondestructive study of crystal structure was performed by means of optical methods: reflectance and photoluminescence, the low temperature (T=1.4 K) spectroscopy and the Raman spectroscopy. We also measured acoustic emission (AE) from the sample, the frequency range of AE measurements was 0.02 to 0.5 MHz. In the experiments we have observed for the first time acoustically stimulated phase transition. It is shown that a dislocation structure is changing under the ultrasonic irradiation. The high stability of the obtained 4H polytype is of special interest. These fact and acoustic emission anomalies are under discussion.

The peculiarities of distributed feedback laser generation on the bases of cubic chiral crystals

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Theoretical models and different calculation methods for the parameters of distributed feedback (DFB) lasers were considered [1]. Light diffraction on the reflective volume holograms in photorefractive cubic crystals is investigated [2]. The specific features of collinear acoustooptic diffraction in chiral absorbing crystals have been studied on the basis of the coupled-wave theory [3]. A set of differential equations has been solved describing the transmitted and diffracted waves for the geometry of interaction with parallel and opposite wave vectors. In the case of chiral cubic crystals the chirality should be taken into account for any geometry of the light and phase grating interaction.

The fabrication and performance characteristics of $Bi_{12}SiO_{20} : Nd_{[3+]}$ lasers with crystallographic [100] emitting direction are reported [4]. The laser have been operated to an output power of 18mW for wavelength 1.0716mm. It was fabricated on the bases of usually used mirrors of Fabry-Perot resonator.

The paper represents the study of distributed feedback (DFB) laser on the bases of a gyrotropic cubic crystals. Phase and amplitude conditions of DFB laser generation is determined. It is shown that single frequency of eigen right- and left circularly polarized longitudinal light modes decreases (increases) on the value of $\omega_p = \rho c/n$ (ρ is the specific rotatory power, n is the refractive indices, c is the velocity of light in vacuum) in comparing with Bragg frequency $\omega_0 = \pi c/n\Lambda$ (Λ is the grating period). The threshold of laser generation for right circularly polarized light wave is bigger then that for left polarized light wave. In the case of acoustically distributed feedback laser generation it must be taken into account additional Doppler frequency shift of the diffracted light waves.

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About surface light waves on a boundary photorefractive crystals with diffusion-drift mechanism of nonlinearity

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The exact solution of a boundary problem of the Maxwell equations is given in an approximation of plane waves in case of surface electromagnetic waves for the boundary photorefractive (FR) crystal - transparent isotropic medium. It is shown, that among all possible kinds of surface waves in case FR crystal with diffusion-drift mechanism of nonlinearity actually can be realized only surface wave of soliton type. The conditions of existence are found and the characteristic parameters of such waves for FR crystal of a type SBN - (strontium-barium-niobate) are determined. The characteristic graphic of dependence of amplitude of a field surface (soliton) wave on depth of damping is represented. The obtained results are of interest in connection with development of systems of transfer of an information.

Nonlinear Fabry-Perot interferometer with built-in sinusoidal diffraction grating

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The theoretical investigations of diffraction of light beams on phase sinusoidal diffraction grating placed between parallel mirrors of a Fabry-Perot interferometer are carried out. The problem is solved on the basis of Maxwell equations in the approximation of plane waves. The wave equation represents the Mathieu differential equation, the solution of which is reduced to an algebraic problem on eigenvalues and eigenvectors. The boundary problem which is formulated afterwards leads to the system of linear algebraic equations which describes distributions of transmitted and reflected light fields for modulated interference system.

The numerical analysis indicates that the power of beam incident on interferometer with a built-in diffraction grating undergoes strong redistribution between diffraction orders depending on such parameters as angle of incidence, initial detuning from the interference maximum and index of phase modulation. This feature provides the opportunity to use such grating-interferometer as an amplitude-phase modulator and a spatial switch of a new type. If non-linear optical media are used as an intermediate layer and grating is formed by interferencing light beams, then the parameters of such a modulator can be changed and controlled optically.

Section B
Laser physics and laser technology

Generation of femtosecond pulses in solid-state lasers with pulsed synchronous pumping

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At present solid-state active media-based lasers have become widespread sources of femtosecond pulses. Kerr-lens mode locking based on the use of loss modulation by Kerr-lens [1] has made it possible to achieve the most striking results both in the development of compact laser systems and in the generation of ultrashort pulses of record-breaking duration. Nowadays all femtosecond lasers utilize continuos working gas (ion) or solid-state lasers as pump sources. We proposed an alternative method [2] for generation of femtosecond pulses due to synchronous pumping of a titanium-sapphire laser by a finite train of picosecond pulses. This method also employs the effect of Kerr-lens as a basis for passive mode-locking. Compared to the traditional systems, time-limited pulse pumping brings into existence the specific features when realizing the mode-locking mechanism. In this report, by using the self-consistent nonlinear ABCD method, we have analyzed theoretically the passive mode-locking mechanism, conditions of pulsed synchronous pumping being taken into account. Stable generation of single femtosec- ond pulses with a duration of 100 fs and energy of 0.5 mJ was provided by the ex- periments. A femtosecond spectrometer based on a laser of this type is described. Since Kerr-lens effect is practically inertialless it can be used for measuring a duration of generated pulses. The results of direct kinetic experiments on induced anisotropy decay dynamics for different-type polyatomic organic molecules in a gas phase over a femtosecond time range are presented.

Acknowledgement

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Laser-induced processes in laser ablation plasmas

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In the present paper processes accompanying the interaction of the intense laser radiation with laser-ablation plasmas have been examined. Plasma was produced by focusing of a Nd:YAG laser radiation (λ=1064nm, 10 ns FWHM, maximal energy 250 mJ/pulse), its second (532 nm, 150 mJ) or fourth (266 nm, 16 mJ) harmonics on the surface of the rotating samples placed in the chamber with helium atmosphere at pressures varying in the range 10^{-3} - 500 Torr. The maximal intensity of about 10^{10} W/cm^2 was created in the focal spot on the target. The details about the densities, time-space distributions of ablated species both in the ground and excited states have been obtained from LIF and OES measurements. With a regular delay the ablated plume was probed by the radiation of the excimer XeCl laser (308nm, 10ns, 10^7 - 10^8W/cm^2), the Ti:sapphire laser (tunable in the range of 690 - 1000 nm), or the second harmonic of this laser (350 - 500 nm). The processes of selective

excitation, resonant photoionization and photofragmentation of molecules and clusters in plasmas have been studied. The results obtained can be used in laser controlled production of ion beams for ion doping and epitaxy as well as for laser stimulation of endothermic chemical reactions by a preparation of excited reagents.

Optical treatment and modification of properties of ZnTe crystals

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Zinc telluride belongs to wide-band gap II-VI compounds which are used for the making of light-emitting diodes, lasers, and photodetectors. In the paper, results of the investigation of influence of different regimes of laser treatment on optical and electric properties of ZnTe crystals are presented.

The optical treatment of undoped ZnTe crystals by the cw laser (1.06 μm) and lamp (0.2−1.1 μm) radiation leads to the appearance in the photoluminescence spectra of a large number of narrow lines which are related to acceptor and neutral complex defects resulting the presence of temperature gradients. The structure of the treated crystals becomes more perfect that is observed in the decrease of the number of pits after chemical etching of the samples. Optical annealing of boron implanted crystals leads to a partial reconstruction of the crystal structure. This procedure allows to prepare light-emitting MIS diodes.

The action of pulse laser radiation on ZnTe may be used in technology of p−n junctions and ohmic contacts. Method of the formation of ohmic contacts to p-type ZnTe at the treatment of samples with a coating metal film by millisecond laser pulses has been developed. The specific contact resistivity for crystals having the volume resistivity of $2 \times 10^2\,\mathrm{O}hm\,\mathrm{c}m$ is about $0.1\,\mathrm{O}hm\,\mathrm{c}m^2$ and does not depend on contact materials used.

Nanosecond laser pulses have been used to change the type of conduction of *p*-ZnTe crystals and to make *p*–n junctions. Based on the *p*–*n* junctions, diode sources emitting in the yellow–green spectral region at 80 and 300 K have been obtained. Current-voltage characteristics and spectra of the light-emitting diodes have been measured and the nature of observed electroluminescence bands has been examined.

Laser measurements of low air pollutant concentration

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An original design of photoacoustic system with CO_2 wave-guide laser was presented to quantitatively determine low concentration of pollutants in real air. As compared to thermal radiation sources, lasers are advantageous due to high spectral brightness, monochromatic radiation directivity, and no continuous background. The CO_2 laser wavelength is tuned in a $9 - 11\ \mu m$ region with IR absorption bands of atmospheric pollutants.

The results obtained show that simple PA gas analyzers can be produced to detect utmost admissible concentrations of numerous air pollutants having absorption lines coincident with CO_2 laser ones by using both commercial CO_2 lasers that provide a power output of $0.1–0.5W$ on a single line and commercial microphones with a sensitivity of about $2.5\ mV/Pa$. With wave-guide CO_2 lasers, resonant PA cell, miniature electronic units, our full-automatic device model sizes was diminished to $600 \times 300 \times 200mm$, not changing parameters necessary for ecological monitoring. A concentration sensitivity of $10^{-8} - 10^{-7}$ limited by air component absorption in the CO_2 laser radiation region was achieved. This value depends on an examined molecular combination absorption cross-section σ and on admixture background absorption. Employing the same radiation sources and electronic units results in a further sensitivity increase in the presence of several microphones and two- channel system.

Nonlinear absorption at 266 nm in BBO crystal and its influence on frequency conversion

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The ultraviolet nonlinear absorption at 266 nm in BBO crystal and its influence on frequency conversion are discussed. We investigated the intensity-dependent loss properties of nonlinear BBO crystal by using nanosecond laser pulses at 266 nm. It was experimentally established that the maximal nonlinear losses for pump radiation were equal $\sim 22\%$ at pump intensity 60 MW/cm^2 in 14 mm BBO crystal. Based on these measurements we have numerically modeled of properties induced defectes which is formed by two-photon absorption of 266 nm light. We determinated the defect absorption cross section at 266 nm to be approximately $6.5 \cdot 10^{-17} cm^2$. A new continiously tunable ultraviolet source with high peak power is presented and investigated in detail. Based on OPA BBO system pumped by fourth harmonic of a Nd:YAG laser UV radiation in the range of 300...400 nm was efficiency genarated. UV energies of up to 10 mj at 327 nm were achieved from a 35 mj of pump energy at 266 nm.

Temperature-tuned cascade third-harmonic generation of a Nd:YAG laser in type II KTP/DKDP crystals

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We present here the demonstration of a temperature-tuned cascade third-harmonic generation (THG) in the KTP/DKDP crystals with type II phase matching. A multimode Q-switched pulsed Nd:YAG laser was used as a radiation source at 1,0642 μm with pulse energy up to 330 mJ, peak power density up to 250 MW/cm^2 and pulse width $\sim$ 5 ns. Linearly polarized fundamental radiation by means of quarter-waveplate was converted into circular polarized light. For second-harmonic generation (SHG) we used a 3-mm-long type II KTP crystal which is placed in a thermostat. To compensate phase difference of unconverted elliptical polarized radiation we installed dichroic waveplate behind the KTP crystal which works as a quarter-waveplate for the fundamental and as full-waveplate for harmonic. For cascade THG we used a type II DKDP crystal. The SHG maximal conversion efficiency was 55 %. The fundamental unconverted radiation at temperatures 31,5^{o}C, 49,5^{o}C and 63,5^{o}C was linear- polarized and inclined 45^o with respect to the z axis of KTP and at temperatures 40^{o}C and 57^{o}C was circular-polarized. At a temperature change from 40^{o}C to 57^{o}C a phase shift between **e**- and **o**-components is equal to π [1]. The maximal THG conversion efficiency is obtained with a KTP crystal temperature of $\sim$ 56^{o}C. The obtained experimental data suggest that by changing in an appropriate way a KTP crystal temperature it is possible to control polarization of unconverted fundamental radiation and, consequently, the efficiency of a cascade third harmonic generation.

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Crystal ↔ liquid phase transitions induced in GaAs by pulsed laser irradiation

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The melting and crystallization processes induced in monocrystalline GaAs by ruby laser irradiation at pulse duration of 80 ns (FWHM) have been studied by means of time-resolved reflectivity (TRR) at λ=0.53 μm and pyrometric (TRP) measurements. TRP measurements were carried out by detection of transient thermal radiation of the laser heated area in a green spectral range at the effective wavelength of 0.53 μm and by using the laser melted Si during crystallization as a calibrated radiator with known brightness temperature and emissivity.

The laser melting threshold of GaAs has been determined to be 0.3 J/cm^2 that it follows from TRR data. The dependencies of the melt duration τ and peak surface temperature T_p on the laser energy density W have been established up to W=1.5 J/cm^2 (τ=1,1 μs, T_p=2500 K). The experimental data obtained were compared with a computer modeling of the processes. The modeling was carried out on the basis of a numerical solution of one-dimensional heat conductivity equation in view of new phase nucleation kinetics in the liquid -solid interface. Two mechanisms of fast crystal growth from the melt were considered. These mechanisms correspond to atomically smooth and atomically rough front of phase transition.

The modeling results agree with the experimental data in T_p(W) and undercooling value of the liquid phase at the initial stage of crystallization. This value is about 15 K and it insignificantly varies in dependence on W. There are specific features in temperature dynamics during crystallization of GaAs in comparison with Si. According to the modeling data the average velocity of the melting front movement in dependence on W

varies from 4 to 9 m/s. The crystallization velocity at the finite stage is equal $\sim$ 1 m/s.

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Dynamics of the annealing of hydrogenated amorphous silicon by excimer laser radiation

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Phase transformations induced in a-Si:H films on glass substrates by 10- nanosecond (FWHM) pulses of ArF excimer laser radiation with λ=193 nm have been studied by means of time-resolved reflectivity (TRR) and conductivity (TRC) measurements and also by measuring (ex situ) dark conductivity (DC) and Raman spectra of the samples. The films had a thickness of 70 nm and were prepared by the radio-frequency low-power glow-discharge decomposition of SiH_4. TRR measurements were carried out by using a He-Ne laser (λ=633 nm) as a source of probe radiation. The probe beam focused in a spot $\sim$0.05 mm in diameter was directed to the sample surface irradiated at an angle of 30^o.

The simultaneous application of TRR and TRC methods allowed clear identification of the melting threshold of a-Si:H (85 mJ/cm^2) and the melt

duration τ in dependence on the laser density W. At the increase of W to $\sim$ 180 mJ/cm^2 the τ value linearly rises to 45 ns. The saturation of a maximum of reflectivity at λ=633 nm for W$\geq$120 mJ/cm^2 indicates that the whole sample thickness is melted. The estimation of the magnitude of conductivity transient for this situation corresponds approximately to the conductivity of liquid silicon.

The DC conductivity of irradiated a-Si:H was measured as a function of W and number of pulses. These results together with Raman spectroscopy revealed that single-pulse annealing gives significant increase of the conductivity of the films but crystallization of Si does not occur, i.e. the transformation from liquid to new amorphous state of the material takes place as a result of the laser irradiation. The presence of crystalline nuclei in the single-pulse irradiated film results in the crystalline phase formation from the melt at the second annealing of the sample. The DC conductivity of at least twice irradiated films corresponds to typical microcrystalline Si:H conductivity values.

Electrooptical conical lenses for Bessel light beams formation

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In present paper the controllable conical lenses for Bessel beams realizing are considered. The operation of these lenses is based on the change of the crystal refraction index under the effect of an electrical field. A direct influence of the electrical field on optical properties of the crystal and accordingly on the direction of optical rays allows us to eliminate the inertial factor imposing the restriction on frequency performance of alternative means of the Bessel beams cone angle control.

The controllable conical lens consists of a plane crystal plate one facet of which is coated with the system of transparent electrodes in the form

of concentric rings and the opposite facet is covered with a continuous transparent electrodes. Electrodes made as the concentric circles are connected via the special voltage divider to the power feed. When the conical lenses are fed an inhomogeneous electrical field is created in the crystal. This field produces a variation of the refraction index decreasing as a linear function of the radial coordinate. The steepness of the linear dependence is changed with an applied voltage variation resulting in tuning of the Bessel beam cone angle.

The inhomogeneous distribution of a refraction index in the crystal for the Bessel beam cone angle control is created by quadruple fields. In this case the crystal is required to possess the dual transverse Pockels effect and the light beam to propagate along the forming electrodes. In this method of the light beam cone angle control a polarization of the input beam is of basic importance. Therefore in this device the special phase polarizer is used.

Effects of quantum confinement on amplitude-phase coupling parameter of semiconductor lasers

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The amplitude-phase coupling parameter, usually known as the linewidth enhancement factor or α-parameter, strongly influences the emission linewidth of semiconductor laser. The stability of lasing regimes of semiconductor laser with external optical feedback also greatly depends on α-parameter. The spectrum of α-parameter is determined by the structure of energy levels contributing to stimulated radiation emission. It was found that quantum-well lasers are characterised by reduced α at lasing wavelength that enhances the laser's performance. In the paper the analysis of different types of quantum-dimensional confinement including quantum-well, quantum-wire and quantum-dot structures has

been carried out. The effects of spectral broadening have been taken into account in the density-matrix formalism. It has been shown that decrease in degree of freedom of electron gas results in decrease of α-parameter in whole spectral range. The magnitude of α-parameter is also changed by the excitation conditions, the doping level and the ratio between effective masses of electrons and holes. Thus from the practical point of view for obtaining of α-parameter, which is equal to zero near the maximum of gain spectrum, the quantum dot structures are most preferable.

Gain spectra optimization of the asymetric quantum-well heterostructures for infrared range

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For high-performance fiber optic systems the infrared lasers of the 1.3-1.6 μm range are necessary. Laser radiation in this range can be reached in quantum-well heterostructures based on quaternary compounds $In_xGa_{1-x}As_yP_{1-y}$ [1]. In the work, gain and luminescence spectra of asymmetric quantum-well heterostructures are analyzed in the four-band k-p- method approach [2] and the wide gain spectrum is achieved.

In quantum-well lasers the wave length corresponding to radiative intraband transitions depends on active layer thickness. For asymmetric quantum-well multiply heterostructures, quantum wells of different thickness amplify the radiation in different wave length range. Therefore the total gain spectrum of quantum-well heterostructure with unequal quantum wells can envelope the wide wave length range. For the total gain spectrum alignment in wide spectral range it is necessary to control the excitation of each quantum well by means of doping of the barrier layers.

The calculations are performed for the asymmetric quantum-well heterostructure which consist of four quantum wells of different thickness.

The barrier layers are formed by $InAs_{0.16}P_{0.84}$ and the quantum wells consist of $In_{0.68}Ga_{0.32}As_{0.88}P_{0.12}$. The parameters of the heterostructure are specially selected to receive unstrained structure with band gap corresponding to near infrared range. It is shown, that for asymmetric multiply quantum-well heterostructures with inhomogeneous excitation of the active layers of different thickness, the wide gain spectrum can be achieved in 1.3-1.6 μm range.

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$LiF : F_2^-$ Color center laser with a low threshold

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At present the $LiF : F_2^+$ and $LiF : F_2^-$ color center lasers are among the best lasers that can be tuned in the vicinity of 1 μm wavelength (they oscillate at room temperature with efficiency up to $\sim 40\%$, the overall tuning range is 0,82 – 1,31 μm). The urgent present-day problem is pumping of these lasers by diode lasers oscillating in narrow spectral bands with high efficiency of electric-to-optical energy conversion.

In experiment the γ-colored $LiF : F_2^-$ crystal of 4 mm length was used with the absorption coefficient k which makes 1,3 cm^{-1} at the maximum of F_2^-–band (λ = 960 nm) and is spectrally neutral in the region of $\lambda > 1170$ nm where it equals k ($\lambda \geq 1170$ nm) = 0,04 cm^{-1}. This crystal was longitudinally pumped by focused pulsed radiation of

flashlamp-pumped $LiF - OH^- : F_2^+$ color center laser at wavelength 950 nm which modeled the radiation of diode laser. Pulse duration was about 1–3 μs. The diameter of beam waist at half-level was 60±5 μm and its length was 10 mm. The resonator consisted of two mirrors with radii of curvature of 50 mm. In this scheme for the $LiF : F_2^-$ color center laser the threshold pump power of less than 1 W has been achieved the first time. For the case when active zone was irradiated preliminary by second garmonic of $YAG : Nd^{3+}$ laser (λ = 532 nm) the threshold was lowered down to 0,3 W. This result encourages the design of $LiF : F_2^-$ laser pumped significantly beyond the threshold by commercial 1 W $InGaAs$ laser diodes emitting around wavelength of 975 nm.

Lasers with intracavity doubling of frequency of the generation

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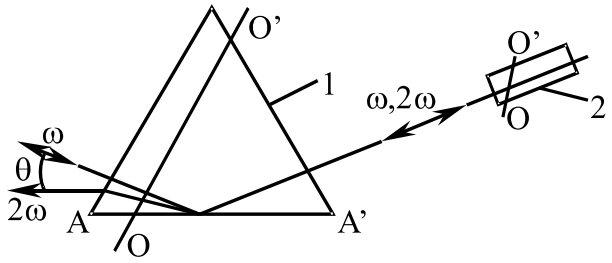
One of ways of increase of efficiency of transformation of frequency of radiation of lasers by methods of nonlinear optics is intracavity transformation of frequency, when nonlinear crystal for transformation of frequency is placed inside the resonator. We use the dispersive-polarization device for the output of radiation of the second harmonic. The laser on YAG with use of a special prism $CaCO_3$ made from a monocrystal was offered for the solution of this problem.

The direction of propagation of interacting waves in a prism is shown in a Figure.

The separation of beams of the basic radiation of the laser and radiation of the second harmonic occurs by means of reflection from a facet AA′, and the angle θ between beams is equal $\approx 12^0$.



Using of a crystal $CaCO_3$ is caused by a significant anisotropy and tranparence of a crystal. The phase synchronism of interacting waves in a nonlinear crystal is carried out by moving of a prism 1 toward an optical axis OO′. The peak efficiency of transformation in created optical system makes $\sim 80\%$, that allows to use such type of the schemes in laser systems.

The analysis of temperature fields generated under electrochemical deposition of metals stimulated by laser radiation

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In the study radially - temporal dependences of temperature in the vicinity of local settlings under laser electrochemical deposition of argentum on a copper substrate under different power densities of laser radiation were experimentally examined.

Using the finite-element method the calculations of temperature fields generated under electrochemical deposition of metals stimulated by laser radiation were made. As a result radially - temporal temperature fields distributions were obtained and graphically displayed which corresponded to experimental ones in the whole range of power densities. The analysis of the dynamics of the process of temperature fields forming has

allowed to find out the mechanism of local metal precipitates formation. The obtained information was used for optimization of parameters of the processes which take place under laser electrochemical forming of local metal precipitates.

Obtaining of diamondlike coats using laser processing and the ion–beam technology

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In the study the method of combined film coating which comprises laser processing and the ion - beam technology is offered. The essence of this method is that the graphite target is situated in the core of a low-energy ion source, made according to the plan of the face Hall accellerator with an open anode layer. The source allows to form an ion beam which has the energy (40 - 200) eV and the angle of the recession of ions $(140\text{-}160)^0$. The laser erosion torch begins to form in the ion source. In such combination the energy of the high-energy part of the laser erosion torch remains practically invariable, as it exceeds greatly the energy of particles formed in the ion source.

The use of a combined method has allowed to increase the energy of the low-energy part of the laser erosion torch, to ionize the neutral component of the particles of the laser erosion torch.

The use of a combined method of diamondlike coating has allowed to obtain films which contain fewer allotropic modifications of carbon and which have sp and sp^2 connections, to increase considerably the square of the evaporated surface in comparison with the evaporation using a pure laser erosion torch.

Diamondlike properties of the obtained films are confirmed by the infra-red methods, methods of visual and ultraviolet spectroscopies, of the spectroscopy of combinational scattering, by the methods of electronic paramagnetic resonance and of the atomic-power microscopy.

Laser glass thermosplitting in mutually orthogonal planes

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This paper is dedicated to a new mode of glass separation with the help of continuous carbon dioxide lasers. The essence of the mode is in the joining into a single cycle of laser operated thermosplitting at the given depth and thermosplitting parallel with the surface. In this case, simultaneously with the split of the parallel glass surface, a microcrack spreads from the surface towards the depth of the glass in the quenching agent feeding zone. Glass thermosplitting takes place on two mutually orthogonal planes.

To make an optimum choice of technological parameters of the process of formation mutually orthogonal splits the information about the distribution of thermoelastic fields formed in the glass is necessary. For the solution of this problem the finite-element method was used.

An examination of laser glass separation in the plane parallel to its surface

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The paper examines the mode of separation of glass cover articles that allows to obtain thin plane-parallel plates. The experimental examinations were carried out by the authors on a laboratory model. In the process of prototyping: a gas CO_2-laser with the average output power of 35 W that works in continuous conditions, coordinate table with program control and a mechano-optical device of an energy channel of radiation were used.

Parallel laser thermosplitting during experimental examinations was carried out by meas of irradiation of the workpiece by an elliptic laser bundle whose small axis is turned in parallel with the direction of travel of the laser beam with regard to the glass plate.

To find out the mechanism of formation of a split that is parallel with the surface the information about the distribution of temperature stresses formed in the glass when it is heated by a laser bundle is necessary. This problem was solved by means of a finite-element method implemented in the university version of the ANSYS program.

The results obtained can be used in the electronic industry for optimization of the process of obtaining thin plane-parallel plates.

Laser thermostrengthening of the high-pressure apparatus dies used for synthesis of supersolid materials

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The exploitation of high-pressure apparatus used for synthesis of supersolid materials takes place in extreme conditions, that results in quick

wear of expensive details of the construction made of solid alloys. Therefore the question of the life extension of the of high-pressure apparatus dies is topical. For the solution of this problem we used the methods of surface laser processing.

The experimental examinations of the process of surface laser quench hardening were carried out on a laboratory model which included a laser head with a power supply unit and refrigerations (a pulsing solid laser on ND: YAG with a radiation wave 1,06 μm long), a drive control unit and a system of scanning of the workpiece.

The examinations allowed to define optimum technological conditions of laser quench hardening of the high-pressure apparatus dies, which ensure extension of their life.

Laser separation of multilayer structures

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The paper studies the process of simultaneous action of laser ray bundles with different wave-lengths (λ_1=10.6 μm, λ_2=1.06 μm) on multilayer ceramic structures.

The numerical calculations of thermoelastic fields formed in the examined patterns using the finite- element method were made. It was found out that high voltages generated by a solid laser on the line ceramics - multilevel metal coating and the local character of these voltages determine the improvement of the results obtained by means of separation of a multilayer material by a two-beam mode. This improvement is in considerable reduction of the size of warpages and chips from the line of separation.

The obtained results can be used in the process of laser treatment of dielectric materials.

Thermoelastic fields formed by ring laser beams at thermostrengthening

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The problem of estimation of temperature fields and fields of temperature stresses, arisen in the zone of a ring laser beam is solved. The calculation takes into account the power density distribution on the cut of a ring beam and the dependence of thermal and physical characteristics of the material (density, specific heat capacity, heat conductivity) on temperature.

The paper presents the comparative analysis of the laser heat treatment conditions of chrome patterns and ones without coat. The obtained results allow to optimize technological conditions and laser processing conditions of articles made of the U8 steel with a chrome-plated surface.

An examination of laser glass separation

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The researches of the mechanism of the laser processing of materials using a solid- state laser YAG : Nd with a pulse and continuos pumping in Q-swithed mode; the experimental researches of structures formed in crystal superhard materials under the influence of the laser radiation were carried out. There were carried out the morfological researches of a

superhard material " almazot " cristal's surface after its laser processing on the crystallografic planes (111), (110), (100).

It is established that after the laser influense on the crystal's surface of a superhard material "almazot " its morfology essentially differs in dependence of the crystalografic plane along which the processing has passed. The strongest changes are observed in the structure of the cutting surface if the processing plane is parallel to the crystallografic plane (111). If the direction of a laser radiation is along the 3-fold symmetry axis of a crystall the speed of the processiing is 1.2 times more than in case if the axis of radiation is parallel directed to the 4-fold symmetry axis.

The results of the researches were used in the creation of the methods of processing of superhard materials by laser radiation.

Calculation of the CO_2 laser-active levels population from spectral distribution of the gain

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Gains measured at the center of vibrational-rotational lines of the main bands of the CO_2 molecule were used to determine, by the least-squares method, the laser-active levels population for active medium of a CW electric-discharge CO_2 laser.

Sol-gel method preparation silica gel-glasses, doped trivalent rare-earth ions for fiber optics applications

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Optical materials prepared by the sol-gel process are of current technological interest. Sol-gel silica glasses doped with rare-earth (RE^{3+}) ions are an important class of optical materials with applications including solid-state lasers, optical waveguides, fiber amplifiers and devices for optical communications.

There is currently a great deal of interest in the development of active glass devices that derive their important optical properties from organic or inorganic species doped into the glass. Among inorganic dopants, several of the trivalent rare earth ions are being investigated for use in lasers and devices for optical communications. Because of the high melting temperature of SiO_2, it is difficult to prepare rare-earth doped silica glasses using the traditional technique involving the quenching of an oxide melt. The sol-gel process provides a convenient alternative method for preparing doped glass samples without melting. The sol-gel method is a low-temperature solution method for glass preparation based on the inorganic polymerization of hydrolyzed metal alkoxides. Metal ion dopants to be incorporated in the final glass product are added to the initial solution in the form of inorganic salts, metal alkoxides or encapsulated metal complexes. The hydrolysis and condensation reactions driving polymerization continue, leading to the formation of a porous gel extending throughout the reaction vessel at the gel point. The porous gel is then dried and densified to form glass.

In this paper, we describe the preparation of rare-earth-doped silica-gel glasses and discuss the infrared properties of silica structure as a function of heat treatment. The samples were prepared from tetraethoxysilane (TEOS), water, ethanol, fumed silica and soluble in a water or ethanol the salts of the RE^{3+}(Er^{3+}, Nd^{3+}, Sm^{3+}) elements.

Preparation by colloidal route and optical properties of rare-earth doped NBS-glasses

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The colloidal method of obtaining of $Na_2O - B_2O_3 - SiO_2$ (NBS) glasses doped with rare-earth metal has been developed. The process of glass preparing included the followings steps: dissolving of boric acid into acetone and acetic acid mixture; preparation of sol-colloid system by adding of fumed silica (aerosil) into the result solution; adding of natrium as $Na(NO_3)_3$ and the salts of rare-earth elements. The reactives have been degree purity 99.99 %. The colloid was dried from room temperature up to 60 ^{o}C with the following heat treatment in the muffle furnace at the temperature 1280-1350 ^{o}C in 4-6 hour. The results of spectral investigations of obtained glasses doped with Ce- and Sm-ions (0,5-4 wt %) are examined. The absorption spectra of Sm-doped glasses are characterised by the number of narrow bands which are corresponded to intraconfigurational f-f transitions of Sm^{3+} ions. The maximum absorption coefficient for λ=1,06 nm is about 2 cm^{-1}. That kind of glasses has a good perspective for using in Nd^{3+} lasers pumping cavity systems as light filters for suppressing of superluminescence radiation which is making worse the density of population of high laser level in Q-switching regime. But their type of light filters has hardly any absorption in UV part of spectra. For this disadvantage eliminating it is supposed to co-activate this kind of glasses by Ce-ions, which have completely cut UV-radiation with λ = 380 nm and re-radiated it in λ=450 nm.

Section C
Electromagnetic theory

Part I
Electromagnetic waves in natural and artificial anisotropic media

Effects of the interplay of dissipation and chirality in magnetoelectric materials

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Certainly a very proper place to discuss the extremely rich variety of possible macroscopic behavior patterns of chiral materials is Belorussia with its great tradition on wave–material interaction studies, and, in particular, the University of Gomel where an active school with focus on magnetoelectric materials, lasers, and other nonlinear phenomena was founded several decades ago. The effect of Academician B.V. Bokut' (and here not forgetting the works of Academician F.I. Fedorov) continues to be felt through his writings and in the scientific output of his younger colleagues and students. Today, to an even greater degree, the results of the Belorussian school are available to the "Western" scientific community (see, for example [1]).

In this presentation I will focus on certain strange and counterintuitive ways in which the magnetoelectric materials can behave on their macroscopic level. It is of course acceptable that complex materials behave in a complex manner but certainly always there are the laws of physics that set unbreakable boundary conditions to the possible patterns of characteristics these materials may display. There exists literature on the modelling of the effective material parameters of chiral and other magnetoelectric composites [4, 5] and some of the "emergent" macroscopic phenomena are discussed in those references. Here, in this presentation, I would like to remind ourselves on these special effects and strange phenomena, and also intend to go somewhat further to phenomena that perhaps have not been given any attention before, even within the bi-anistropic community.

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[5] A. Sihvola: Electromagnetic mixing formulas and applications. (Electromagnetic Waves Series, Vol. 47, 284 pp.) The Institution of Electrical Engineers, London, 1999. —See also [6] for a discussion of some unintuitive properties in the macroscopic behavior of composite media.

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Properties of Stokes radiation in the forward and backward directions for stimulated Raman scattering with Bessel pump beam

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During the last years there has been strongly increased interest in stimulated Raman scattering (SRS) with Bessel pump beams. Employment of quasi-diffraction-free Bessel light beam (BLB) allows to realize the longitudinally-homogeneous pumping.

In addition to the known SRS description based on gain-guided modes we developed new model based on the theory of spatial dispersion. This model allows to explain the experimentally observed SRS properties such as a difference in conicity angles for Bessel Stokes beams generated in opposite directions and generation of nearly diffraction-limited axial Stokes beam under conditions below cutoff.

The SRS with BLB pump has been theoretically studied using three approaches: i) analysis of overlap integrals, ii) calculation of the effect of the limited Bessel Stokes beam diffraction length upon the gain, iii) the mode model for Stokes beam generation. The correct calculation of overlap integrals with the use of normalized Bessel functions reveals the absolute maximum in the gain of Stokes radiation at the spatial frequency q_0 of BLB pumping. It is observed when the BLB diffractionless zone length is larger than the length of Raman cell. Otherwise, the

gain maximum can be realized at the spatial frequency $q_s < q_p$, that is attributed to the increase in the interaction length with decreasing q_s, i.e. the cone angle. The presence of another maximum in the overlap integral corresponding to generation of the axial almost diffraction-limited Stokes beam has been also observed.

SRS experiments were carried out in H_2 (pressure P = 50 atm., cell length L = 2.8 m). The second harmonic of a single-mode single-frequency Nd:YAG laser was used for pump radiation. The Bessel pump beam was formed by an axicon and had a cone angle of $\gamma = 1.85$ mrad. With the backward Stokes scattering, the effect of the decreasing cone angle of the Bessel beam, compared to that of the direct Stokes scattering, has been revealed. This effect was explained taking into account the decrease in the efficient interaction length for the backward Bessel Stokes scattering that is in agreement with the theoretical calculations.

Exotic composite materials: a review of recent developments

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In this presentation we will review recent developments in the field of exotic composite materials, mainly of spatially dispersive composites with complex-shaped or loaded inclusions. The emphasis will be on two research directions: very thin (compared to the wavelength) layers and materials with unusual properties, such as materials in which both the permittivity and permeability are negative. We will show that certain arrays of planar metal particles located very near to a metal ground plane exhibit resonance properties due to interaction with the ground plane (usually, cancellation with the image currents occur). This opens a way to design very thin covering layers which transform electric walls into magnetic walls. Regarding complex volume composites, we will discuss, among other issues, the means to provide negative permittivity and permeability which can make it possible to design novel lenses.

Complex eigenmodes of planar waveguides with pseudochiral omega media

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The pseudochiral or omega medium is an artificial complex medium obtained by doping a host medium with omega shaped conducting microstructures. We investigate the occurrence of complex modes on planar waveguides containing pseudochiral media. In a dielectric asymmetric pseudochiral waveguide in which both the film and the substrate are pseudochiral media but with an isotropic superstrate, it is shown that, when the pseudochiral parameter exceeds a certain transition value, power leakage occurs. These modes are termed semileaky modes since one of the two characteristic waves is not internally reflected at the film-substrate interface. Numerical results are presented for the phase and leakage constants of the semileaky modes.

Reflection and transmission by a bi-anisotropic omega structures under normal incidence of plane waves

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In this paper plane wave reflection and transmission phenomena in slabs of artificial bi-anisotropic media are theoretically considered. The

artificial structure is a so-called *omega* composite which is formed by embedding small Ω-shaped particles in an isotropic host-medium. Normal incidence is assumed. The boundary-value problem for artificial omega structure was solved taking into account multiple reflections of electromagnetic waves from the sample's boundaries.

Acknowledgement

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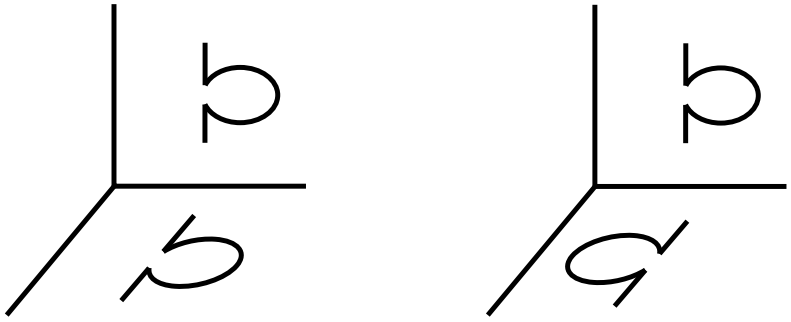

Figure 1. Geometry of the omega structure

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Electromagnetic properties of a plasma medium in crossed static fields

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The electromagnetic properties of a cold unicomponent plasma medium affected by orthogonal static fields were considered in many textbooks [1]. Here the case of arbitrary field directions reduced to the parallel case by introducing a properly choosen moving coordinate system is investigated. The expressions for the constitutive parameters in the Post representation are derived. The influence of the static electric field results in the magnetoelectric coupling. It is shown that such a medium belongs to the class of Faraday chiral media conceptualized earlier as heterogeneous mixtures consisting of gyrotropic and chiral components

[2, 3]. The difference between wave phenomena in usual gyrotropic media and in plasmas in parallel static fields is investigated for plane wave propagation along the distinguished axis of the medium. The solutions of the dispersion equation representing the right and left circularly polarized eigenwaves were found explicitly. The presence of the static electric field results in two basic effects: the increasing of the pass–bands and the decreasing of the imaginary part of wave numbers in the stop–bands. This property can be used as the background for a new method of plasma diagnostics.

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Resonance losses in bianisotropic composites

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An important step in the homogenization technique is the evaluation of the so–called *depolarization dyadic*. Recent efforts allow to derive its explicit expression for the elliptical–shaped exclusion region in general linear bianisotropic environment medium in the long–wavelength approximation [1]. In this contribution, media, of which material parameters provide the divergent behavior of the depolarization dyadic, are considered.

The conditions providing the presence of a singularity in corresponding two–dimensional integrals coincide with the resonance conditions for bulk plane waves. The explicit expression for the depolarization dyadic in the singular case is evaluated. It consists of two parts: the real–valued two–dimensional integral with excluded singularity and the imaginary part due to integration on the singular curve. The second part does not depend on the dissipation processes in the environment medium and changes sign, when the conservative limit of active medium is taken. It results in the lossy part of the effective parameters of mixture with singular background. These losses are investigated for gyrotropic environment. In certain frequency domains the resonance losses are significant. In principle, one can create a mixture, of which material parameters will consist of the lossy part only.

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Singular waves in chiroplasma waveguides

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Specific waves, of which phasor has linear spatial dependence, were singled out in anisotropic crystals [1], gyrotropic [2, 3] and certain bianisotropic media [4]. In this contribution, such singular guided waves in bounded chiroplasma, of which parameters provide the degeneracy of

wave equation in sagittal plane, are investigated. Two kinds of parallel–plate waveguides — a waveguide with both electric walls and a waveguide with both magnetic walls — are considered. The dispersion equations are derived and examined by semi–analytical tools. Two kinds of bi-directional waves — the slow surface–like mode having imaginary transverse wavenumber and the fast mode with purely real one — can propagate in the low–frequency band, where the degeneracy is possible. The slow modes propagate in upper part of this band. They transform themselves continuously to the unidirectional surface waves, when the width of the waveguide increases to the infinity. The fast modes are supported by the waveguide in the lower frequency domain. The widening of the waveguide enriches the spectrum of popagating modes but leads to the disappearance of the fast region.

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Absorption of far infrared electromagnetic radiation by disperse systems with metal inclusions

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Numerous experimental studies of the processes of absorption of electromagnetic radiation (EMR) of far infrared range (4 – 100 cm^{-1}) in matrix disperse systems (MDS) with metal inclusions resulted in establishing some peculiarities that still remain unclear. Some of them are:

i) a large magnitude of the absorption coefficient $\alpha(\omega)$ that exceeds by two orders the most reliable theoretical predictions;

ii) in a range (4 – 100 cm^{-1}) a magnitude of the absorption coefficient $\alpha(\omega) \approx K\omega^2 f$, where K is a constant depending on structure of MDS, f is the bulk fraction (ratio of the metal fraction to a total volume of MDS).

We have calculated a frequency dependence of $\alpha(\omega)$ MDS with spherical inclusions at $f < 0.2$. In spite of the existing theories, the calculation was carried out with the help of exact formulas of the theory of the absorption cross-section of individual particles. This allows us to analyze the frequency dependence of $\alpha(\omega)$ in a wide range of a frequency ω. The results obtained are in a good agreement with experiment. It is shown that a maximum magnitude of the absorption coefficient for a fixed wave length λ_0 (or frequency) corresponds to values of σ_0 or a_0 that may be found from the relation

$$a_o^2 \sigma_o \approx \gamma^2 \lambda_0 / 4\pi (\varepsilon_0 \mu_0)^{1/2}$$

where $\gamma_0 \approx 4.84$, ε_0 and μ_0 are the vacuum permittivity and permeability.

Experimental investigation of polarization plane rotation of U.H.F. waves scattered by metal helix

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In the last years the attention of scientists was attracted to studying of media which can transform polarization of electromagnetic waves of U.H.F. range [1-4]. This is connected with the discovery of new technologies, allowing to manufacture corresponding materials [5], appropriate for the use in millimeter and submillimeter waves ranges, and possibly useful in the U.H.F. techniques. Such media can be created, for example, on the basis of metal helix elements.

For optimization of parameters of such media it is necessary previously to study interaction of electromagnetic fields of a microwave range with a separate metal helix in a free space. The investigation of influence of parameters of separate spiral on polarization of scattered waves is the main aim of our paper.

The investigation carried out in an anechoing chamber with the sizes (12m, 8m, 3m) in a frequency range 2.5 - 4 GHz. The metal helixes are explored, which lengths satisfy to the following relation

$$L_n = n\frac{\lambda}{2}, \tag{1}$$

where n=1,2,3, and λ=10 cm is wave length.

The frequency dependence of the angle of polarization plane rotation of scattered wave for various helixes in the specified frequency band was experimentally determined.

Acknowledgement

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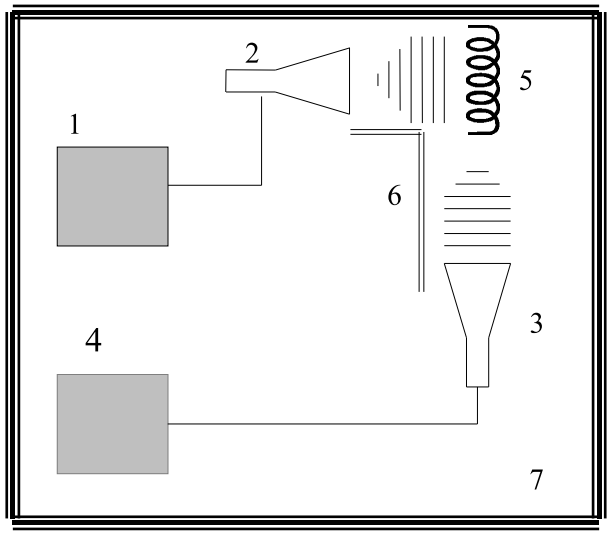

Figure 1. Scheme of the experiment. 1 is generator GCH-80 (2.6-4.0 GHz), 2 and 3 are antennas P6-28, 4 is receiver P5-5B (2.35-4.0 GHz), 5 is the helix, 6 is absorbing screen, 7 is anechoing chamber (12m,8m,3m)

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Polarization properties of Bessel-Gauss light beams

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In a reality, any light beams are limited in space. Therefore for non-diffractional light beams more realistic, though also more difficult, model is the Bessel-Gauss one, for which the cross distribution of amplitude of a field is described by product of functions Bessel of the first kind on Gauss function . In the present work the general vector solutions of the Maxwell equations and vector wave equation of Helmholz, describing Bessel-Gauss beams of light, are obtained. The new types of light beams with Bessel-Gauss cross-section structure of electromagnetic fields propagating in homogeneous isotropic medium are found. The complete solutions for all, including longitudinal, vector components of electric and magnetic fields are obtained. The polarization characteristics of various types of Bessel-Gauss light beams are found. Elliptically polarized modes are described. It has been shown, that azimuthal dependences of an electromagnetic field for linearly polarized modes are expressed more brightly. For circular modes azimuthal dependences of the field are disappearing and all expressions became simpler. It has been determined and analyzed the interrelations between various modes of nondiffractional fields in the cartesian and cylindrical systems of coordinates. The obtained results can be used at the description of mutual transformations of Bessel-Gauss light beams of various types.

Polarization and energetic properties of Bessel wave fields

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Recently major attention of the scientists is attracted with Bessel light beams, frequently termed nondiffractional, at which the cross-section distribution of field amplitude is characterized by Bessel functions of the first kind. In the paper the new exact solutions of Maxwell equations and vector wave equation of Helmholtz featuring new types of modes of Bessel electromagnetic fields in homogeneous isotropic media are obtained. It has been shown, that the set of the solutions is multiparameter and consequently there is an arbitrariness in a choice of the basic types of modes. The polarization peculiarities of various types of Bessel wave fields are found for TE and TM-modes, for linear, circular and elliptic modes. The basic properties TE and TM of modes are obtained. The principle of reciprocity permitting to realize transition from E-modes to H-modes and back is justified. It has been established and analyzed the connections between various modes of nondiffractional fields in cartesian and cylindrical systems . The energy characteristics are calculated and the expressions for average density of energy and Poynting's vector of various types of Bessel waves fields are obtained. The found results can be used by description of mutual transformations of Bessel light fields of various types.

The problem of radar absorbing materials from the standpoint of the filters theory

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Exact solution for the problem of optimal performance of radar absorbers is known only in some particular occasions. The synthesis of optimal absorbers is usually performed making use of numerical methods. The results yielded by numerical optimization of different designs of dielectric radar absorbers, such as single-layer and multi-layer Salisbury screens [1] and Jaumann screen [2] are the evidence of the fact that the

shape of optimal frequency dependence of the reflectance is a function of the number of interference minima incorporated within the operating frequency band only, being independent of the design details.

These results can be readily understood on the base of the universal integral relation governing the frequency dependence of reflectance $R(\lambda)$ of an optimal radar absorber. This relation is derived in [3] as

$$\int_0^\infty |\ln R(\lambda)| d\lambda = -2\pi^2 \mu d$$

where μ and d are the permeability and thickness of the absorber. Therefore, the requirement of the minimal thickness in the problem of optimal performance of radar absorber can be substituted by the requirement of minimal value of integral in the left part of the above equation. Consequently, we can rewrite the problem in terms of the search for optimal frequency dependence of reflectance and apply well elaborated theory of frequency filters to find a solution. In the course of that, the details of the design of radar absorbers become insignificant, and an analytical solution are available for radar absorbers of complicated design.

The work reports some results of this treatment. The data presented allow more understanding to be obtained for the results of numerical study of optimal performance of radar absorbers.

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Application of the new characterictic geometric function for modelling of magnetic composites

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Accordingly to the general theory of composites, which was developed by Bergman [1] and Milton [2], there is an universal "characteristic geometric function" describing both the effective dielectric constant as a function of components' permittivity and the effective permeability as a function of components' permeability. This function is a complex one with a finite number of simple poles. The set of these poles and residues of the geometric function contains complete information about the microstructure of the composite.

A number of models of composites, which are usually called "mixing formulas", are known. The mixing formulas relate to the general Bergman-Milton approach as approximations of the rigorous geometric function of composite under investigation and can be attributed to one of the two basic classes, namely, one-pole approximations (like the Maxwell Garnet formula) and approximations with a quasi-continuous distribution of poles (like the Bruggerman theory).

In the present work we investigate the geometric function and magnetic properties of the filling agents for composites with wax matrix and magnetic inclusions of two types: the carbonyl iron and the FeCrAl alloy. We used coaxial method to measure the dielectric constant and permeability of such composites within the 100 MHz – 10 GHz frequency range and 0.5 – 65 % volume fraction range. On the base of these experimental data we obtained approximations for the geometric function by the use of the processing the data on the frequency dependence of permeability and dielectric constant simultaneously.

Acknowledgement

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Extremely asymmetrical scattering of electromagnetic waves in arbitrary periodic arrays

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It has been investigated extremely asymmetrical scattering (EAS) of waves in periodic arrays. That is realized when the scattered wave propagates parallel or almost parallel to the boundary of a strip-like periodic array. EAS has great possibilities for practical applications in the development of narrow- band optical filters, resonators, switches, lasers, optical sensors and measurement techniques. In the report it has been analyzed the influence of slowly varying grating amplitude and anisotropy of media forming the periodic structure on the extremely asymmetrical scattering. Coupled wave equations describing EAS in anisotropic arrays with slowly varying grating amplitude are derived. The field structure in the scattered waves is determined inside and outside the array. It has been found the regions of variations in the grating amplitude for which the structure of scattered field isn't variable. It has been established essential dependence of pattern of EAS on polarization of incident light. The main features of EAS in such non-uniform anisotropic arrays were explained by the peculiarities of diffractional divergence of the scattered waves. The obtained results will be important for development of new EAS- based structures and devices in optical and acoustic signal- processing, communication and sensor design.

Electromagnetic waves in non-limited and limited superlattices by the presence of impurity layer

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It has been investigated the peculiarities of propagation of electromagnetic waves in superlattices (SL) formed by anisotropic layers by the presence of impurity. It has been obtained and analyzed dispersion equation. It has been established the dependence of zone structure of volume electromagnetic waves spectrum on polarization of incident light, anisotropy of SL components and impurity. It has been shown that spectrum of light radiation qualitatively changes by disorientation of crystallographic axes of layers. It has been found expression for impurity modes. It has been established dependence of orientation of their maxima on polarization state of incident light. It has been shown that use of impurity modes as lasing modes permits to enhance the lasing gain. It has been established the dependence of generation regimes of given lasing systems on change of polarization state of incident electromagnetic radiation.

Superresolution at reconstruction of a permittivity profile of an optical waveguide from its far-field radiation pattern

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Reconstruction of permittivity profiles $\varepsilon(\mathbf{r})$ of inhomogeneous optical waveguides is one of the basic problems of the integrated optics. The most universal way to its solution consists in searching for the lateral

component of the mode electric field $\psi(\mathbf{r})$ whose substitution into the wave equation leads to the direct formula for $\varepsilon(\mathbf{r})$. This paper is devoted to reconstruction of the functions $\psi(\mathbf{r})$ and $\varepsilon(\mathbf{r})$ by the processing of a far-field intensity distribution formed by irradiation of the fundamental mode from a waveguide end face. The proposed approach is applicable to investigate both optical fibers with two orthogonal axes of symmetry in their cross section and channel waveguides. The artificial symmetrization of the waveguide by the mirror surface is implied. Since finiteness of the spectrum of far field spatial frequencies imposes the principal restriction onto accuracy of $\psi(\mathbf{r})$ reconstruction, main attention in the repaper is devoted to obtaining an analytical continuation of the mode field Fourier transform $\hat{\psi}\,(k_x, k_y)$ onto the whole plane of the spatial frequencies k_x and k_y from an experimental range $k_x^2 + k_y^2 \leq a$. Such continuation is known in the theory of inverse source problems as a solution of the problem of superresolution. Being incorrect, this problem is resolvable in the only case when the class of the functions to be found is specified. We deduce from the wave equation analysis and the theory of entire functions that the function $\hat{\psi}\,(k_x, k_y)$ at any k_x and k_y can be interpolated by the expression

$$\hat{\psi}\,(k_x, k_y) = \exp\left[-\alpha(\vartheta)k^2\right]\left(k^2 + \gamma\right)^{-1} \sum\nolimits_{i=1}^{n} C_i(\vartheta)k^{2i}, \qquad (2)$$

whose error monotonically decreases when n insreases. Here k and ϑ are the polar coordinates of the plane of the spatial frequencies and the functions $\alpha(\vartheta)$, $C_i(\vartheta)$ and the constant γ are uniquely determined from the far-field intensity pattern by the least-square method. It is shown that the expression (1) permits to reconstruct $\varepsilon(\mathbf{r})$ with subwavelength resolution. Results of investigations of different waveguides are presented.

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Exotic bianisotropic media

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In spite of some restrictions and constrains, the range of generally bianisotropic media is very broad. Beside the wellknown kinds of bianisotropic media in which there are two positive and two negative eigen waves for any direction of propagation of an electromagnetic wave, these restrictions do not forbid the existence of exotic bianisotropic media (EBM) with a different set of eigen waves. Three cases can be emphasized: (1) all four waves propagates in the same direction, (2) three waves are positive and one wave is negative, (3) two waves of the same polarization are positive and two waves of another polarization are negative. Such EMB are impossible in the framework of anisotropic media which have zero magnetoelectric dyadics. Accordingly, this effect is essentially bianisotropic. The prerequisite of the existence of EBM is that magnetoelectric dyadics must be significantly different from zero, strictly speaking, must be of the order of unit. It was shown [1] that such parameters may appertain to effective constitutive properties of some periodic structures. There is no contradiction if we describe wave propagation in an infinite EBM. The first issue arise when the boundary problem is solved. In the classical solution of this problem, when electromagnetic wave is incident from usual medium, it is assumed that the amplitudes of two negative waves in the investigated medium are zero. In case of EMB, it may be more or less than two negative waves that results either in indefiniteness or absence of solution. In the present paper, it is also investigated another problem which comes into notice if we consider an EBM slab. It emerges that EBM is neither transparent nor absorbing nor amplifying medium. The total reflected and transmitted energy periodically depends on the thickness of the slab.

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Circularly polarised electromagnetic wave scattering on bi-isotropic full-sphere in chiral medium

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A boundary problem about plane circularly polarized electromagnetic wave scattering on bi-isotropic full-sphere located in natural chiral medium is solved. Exact analytical expressions for the electromagnetic fields inside and outside the full-sphere are obtained. Expansion of all waves on the full and orthonormalized system of spherical vectors is used for the solution of the problem.

Particular cases are discussed:

a) the containing medium is not naturally chiral, but magneto-dielectric isotropic,

b) the scattering full-sphere is not bi-isotropic, but chiral, having parameters different from the containing medium.

It is shown that our solution coincides in these two particular cases with known solutions [1, 2].

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The oblique incidence of electromagnetic waves on gyrotropic stratified periodic structures

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One of the possibilities of creation of controlled converters of electromagnetic waves polarization is the use of stratified periodic structures, combining the properties of their components.

We consider stratified periodic structure, consisting of any quantity of elementary cells, placed in an external magnetic field. It is supposed, that the first layer of such a cell is isotropic, and does not possess the gyrotropic properties. The second layer is also isotropic, however it possesses the gyrotropic properties, that leads to circular birefringence of waves inside the layer.

From the continuity equations and the exact solution of the Maxwell equations the elements of a matrix are obtained. This matrix connects complex amplitudes of electric and magnetic fields of an incident wave with the same characteristics of transmitted and reflected waves. Multiplying boundary matrixes and matrixes of propagation in a medium, we obtain resulting matrix for the elementary cell connecting an incident wave with reflected and transmitted waves. Obtained amplitudes of reflected and transmitted waves satisfy to the law of conservation of the electromagnetic field energy.

When changing either an external magnetic field or an angle of incidence or the frequency of electromagnetic waves the polarization properties change both of transmitted and reflected waves. As a result there is the possibility to use such a structure, which has selective reflection of light, as the polarization converter controlled by a magnetic field.

Electromagnetic waves in absorbing artificial chiral media with anisotropic dielectric and magnetic properties

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The characteristics of electromagnetic waves transmitted through artificial chiral media which is placed on a surface of metal layer were investigated. The boundary-value problem for a case of normal incidence of electromagnetic waves on layered structure is solved. Characteristics of structure which are necessary for decreasing of intensity of a reflected wave are calculated. The wave absorption in a medium and metal as well as frequency dispersion of properties of medium was taken into account. The influence of permeability of artificial chiral anisotropic medium on intensity of a reflected wave is investigated.

Calculation of electromagnetic field upon an antenna lattice

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On the basis of the Maxwell equations, a method is developed for calculation of electromagnetic field upon an antenna lattice with the radiotransparent shield using the distribution of electromagnetic field at the near zone.

The peculiarities of propagation of electromagnetic waves in moving optically uniaxial medium

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Using covariant method which was proposed by academician F.I. Fedorov the peculiarities of propagation of electromagnetic waves in optically uniaxial medium which moves with relativistic velocity are investigated. The relativistic generalization of constitutive equations is obtained. The solutions of equation of normals are found. The dependence of behaviour of surfaces of refractive indexes on velocity of medium and polarization of eigen waves are investigated. The relations between components of material tensors are determined.

The analysis of chiral scatterers by a method of the integrated equation

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The methods of solving the task of scattering of plane electromagnetic wave by single chiral elements, such as a helix loop with attached rectilinear conductors, omega-shaped conductor, are described. The analysis is based on the numerical solution of integral equations (IE) for current distribution in thin conductors. The solution of IE is found by the collocation method using step-function as the basis. By the known

current distribution the calculations of the scattered field characteristics are performed.

Numerical experiments were carried out enabling us to learn the influence of the form of a chiral element on scattering characteristics of co- and cross-polarized components. One has learned the dependence of polarizing characteristics of a scattered field on the parameters of the incident wave and scatterer's geometry. We have shown the possibility to control the polarization of a scattered by a chiral particle field for definite range of frequencies by choosing the geometrical parameters of a particle. The influence of rectilinear conductor length and chiral element loop radius on the value of radar cross-section scattering of co-polarized and cross-polarized field components was evaluated. The results of scattering characteristics analysis of a scattering system are given. The authenticity of the obtained results is proved by test calculations.

Eigenmode properties of a parallel-plate chirowaveguide filled with mirror-conjugate media

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A successfully revealed accordance between the plane-wave interactions with a solitary perfectly conducting plane surface restricting a chiral medium and with an interface of two mirror-conjugate chiral media points to the imaging concept [1], but direct usage of the image theory for chiral media is difficult in general. In the presentation, we intend to check how the image concept manifests itself if the above interface is placed between two perfect plane conductors.

A dispersion relation for eigenwaves of such a chirowaveguide is derived using Bohren decomposition. It is factored on four multipliers. The

multipliers are recognized as dispersion relations which correspond to a homogeneous wholly filled parallel-plate chirowaveguide with both electric walls and to analogous waveguide with mixed (one electric and one magnetic) walls.

Although the eigenmode spectrum of a parallel-plate chirowaveguide with identical walls has been studied repeatedly, beginning with [2] and ending in [3], unclear points remain. The presentation determines loci of all mode crossovers on the extended dispersion-diagram plane, and establishes a distinct connection between a serial number of every bifurcated mode pair and a complete set of its crossovers both in the propagation and below-cut-off regions. Then, for the first time, the eigenmode spectrum of the parallel-plate chirowaveguide with mixed walls is investigated by this technique. The entire dispersion-curve pattern for the initial inhomogeneously filled waveguide is superposition of such diagrams for both auxiliary chirowaveguides.

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Analytical investigation of wave behavior in Faraday chiral media

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Various Faraday chiral media (chiro-plasma, ciro-ferrite) have been studied in many works. However behavior of a wave propagating in arbitrary direction within infinite media has not been investigated analytically. Wavenumbers of eigenwaves have not been written in analytical form as these are the solution of the fourth order algebraic equation $k^4 + a_2k^2 + a_1k^1 + a_0 = 0$. Therefore the expressions of field components have not been written in analytical form.

In this work an infinite faraday chiral medium is considered. It is assumed that a plane harmonic wave propagates at arbitrary direction. The analytical method of investigation is proposed. The expressions of the wavenumbers and the field components of the eigenwaves are found in analytical form.

A semi-infinite Faraday chiral medium is also considered. The direction of external magnetic field (anisotropic axis) is not normal to the interface and is not in incidence plane. The wavenumbers of the refracted waves are obtained in analytical form. The refraction angles are found. The expressions of the reflection and propagation coefficients are obtained in analytical form. The expressions of the field components of the refracted waves are obtained in analytical form too. The expressions of the Poynting's vector components of the refracted waves are obtained in analytical form.

The numerical example is considered. The dependence of wavenumbers on frequency and angle propagation is studied. The semi-infinite Faraday chiral medium with typical parameters is investigated using this method.

Influence of external electric field on optical properties of thin films of nonlinear metal composite

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The bulk effective dielectric permittivity of nonlinear metal composites $\tilde{\varepsilon}$ is very sensitive to their microstructure and the dielectric permittivity of metal fraction $\varepsilon_m = \Re\varepsilon_m + i\Im\varepsilon_m$ and dielectric fraction $\varepsilon_d = \varepsilon_0 + \chi|E_L|^2$ (χ is the nonlinear Kerr coefficient, E_L is the local field in an inclusion of the dielectric fraction). Inclusions of metal fraction result in the resonant absorption of electromagnetic radiation by the metal surface modes. Their frequency ω_s may be approximately obtained from the equation

$$\Re\varepsilon_m(\omega_s) + 2\varepsilon_d(E_L, \omega_s) = 0.$$

In the electrostatic approximation, the local field is obtained from the cubic equation and depends on the incident field E_i. The resonant absorption in the system considerably enhances the nonlinear part of ε_d in the vicinity of ω_s, and the nonlinear connection between the local and applied field leads to the so called induced optical bistability (IOB).

We study the conditions of IOB emerge depending on the system parameters. It is shown that IOB appears in the frequency range where the surface modes exist and IOB is suppressed by dampings existing in the system. In this communication we have considered the important example of artificial anti-reflection of thin films of these composites.

It is shown that application of a constant electric field E_0 of the order of $10V$ to the films of definite structure and of a thickness of $1\mu m$ may produce the anti-reflection effect up to $40\% - 80\%$ at practically zero transparency at $E_0 = 0$.

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This work was supported partly by the National Science Foundation through the Faculty Early Career Development (CAREER) Award ECS-9624486 and an Easter Europe Program Supplement.

Limiting rate of the information transmission by electromagnetic field to the electronic subsystem in solid state medium

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On the base of the number-state model the limiting rate characteristics are investigated of process of the information transmission by an electromagnetic field to the electronic subsystem in solid state medium. The characteristic feature of the present investigation is that the transmission is considered between objects the information carriers in which comply with different quantum statistics. It is shown that for finding the limiting characteristics it is necessary to consider the transmission of signals with pulse time which does not exceed the mean free-path time of electron (for GaAs this value is about 1 ps). On the base of negentropy principle the expression for rate of the information transmission is obtained. It is shown that there is a range of a signal power and a spectrum width of the electromagnetic field where the rate of the information transmission is determined by the limiting characteristics of the electronic subsystem. This result confirms the following conclusion. Though the use of electronic information systems is energetically more favourable than electromagnetic one, there is a region of parameters (equilibrium noise power, spectrum width, signal power) where the electromagnetic systems are preferable.

Solution the wave equations for biisotropic medium

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In the paper had been obtained solutions of wave equations describing electromagnetic processes in a chiral medium. Wave equations hade built in projections on axis of cylindrical coordinate system r, φ, z. Waves propagate toward the longitudal coordinate z. A components of electromagnetic field depend on coordinates φ and z as $exp(in\varphi + i\Gamma z)$.

Wave equations are a system of two single-line differential second order's equations with variable coefficients for longitudal components. Analysis of this equations had showed that waves in this medium have as electric, so and magnetic longitudal components and had pertained to the class of hybrid waves.

Obtained solutions of wave equations are generalizations in specified frames all known in the literature of solutions describing propagation of the electromagnetic waves in isotropic, chiral, biisotropic medium. Such statement is based on executed transition from it to specific solutions of wave equations. Obtained results are base for modeling of broad spectrum of functional devices and developments of methods of measurement of parameters of material.

Lithium niobate integreated optical sensors of electric field: theoretical aspects of sensitivity

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The new schemes of electric field strength and direction sensors containing planar electrode systems situated on a lithium niobate crystal surface and channel optical waveguides are proposed. The effect of amplification of detected signal due to redistribution of a charge density in the electrode systems is found. The problem of sensitivity of the Mach-Zehnder interferometric sensors using electrooptic effect in Ti- diffused channel waveguides is studied in details.

Low temperature microwave impedance of aluminum in orthogonal magnetic field

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The real part of surface impedance of aluminum in the range of decimeter wave length have been investigated by the method of registration the Q-factor of coaxial resonator. The resonating system was situated in the magnetic field of helium cryostat. It has been observed that surface impedance is non-monotonic function of magnetic field. On the picture of weak total increase of resistance with magnetic field growth there takes place local negativity of surface magnetoresistance in the region of 2 T. The surface impedance negativity belongs to quasi-resonant movement of electrons situated beyond of central section of Fermi surface. There are two characteristic groups of electrons taking place in charge transfer. Central section electrons have small drift velocity through the skin layer but don't enlarge high frequency conductivity in the region of high magnetic field. They drift in normal direction to electric field and the displacement along electric field direction decreases for these electrons with the magnetic field growth. Second group electrons belong to non-central sections. The part of these electrons being in the skin-layer for the time of the order of Larmor period get electric field energy efficiently. These electrons also drift in transverse direction however these electron groups is able to enlarge surface conductivity because their displacement along field direction is of the order of Larmor radius. For the microwave range the next relations between the basic parameters having the frequency dimension are $\omega \ll \Omega \ll \tau^{-1}$ for high magnetic field and $\Omega \ll \omega \ll \tau^{-1}$ for weak magnetic field. Here ω is the microwave frequency, Ω is Larmor frequency, τ^{-1} is the frequency under interaction with the structure defects. At this process the static conductivity tensor in magnetic field $\sigma = \sigma_o / \left[1 + (\Omega\tau)^2\right]$ is modified due to skinning phenomena. The most include to surface conductivity is ensured with first electron group being in skin-layer δ for the time of τ due to small normal component of

Fermi velocity v and the second electron group being in skin-layer for the Larmor period. As a result the conductivity can be represented as

$$\sigma_{ef} = \sigma_0 \left(\frac{\delta}{T_\Omega} + \frac{\delta}{\tau} \right) \frac{1}{v} \frac{1}{1 + (\Omega\tau)^2}$$

This expression shows the behaviour of conductivity in all range of magnetic field. For the limit case of weak magnetic fields the conductivity speeds to the expression being valid under anomalous skin-effect. Under another limit case the conductivity speeds to zero. Under the intermediate conditions there must take place a weak maximum which have been observed at surface impedance as a quasi-resonance energy absorption on non-central electrons.

Electron iso-energetic surface openness and helicon type wave in metal

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Magnetic field stimulates the propagation of transverse waves in metal for example helicon and Alfen-type. Helicon waves take place in metals having uncompensated electron and hole volumes. These waves exist due to specific static conductivity tensor having off-diagonal hall components of high value before diagonal components. Here the task of possibility of existence of similar type wave in metal having open iso-energetic surface is discussed. In other words what is the role of dispersion law anisotropy in limit case. To answer this question it is necessary to analyze microscopic task of connection between field and charge movement in given point and to make the total macroscopic analysis in accordance with wave equation. The first part of task is based on differential kinetic Boltzman equation with the respective boundary conditions. However for long wave limit being under this analysis the electric field varies slowly on the space. So it is possible to apply the conductivity tensor in the limit of homogeneous electric field. Such tensor representation is peculiar

to static charge transfer. For the standard form of wave $\tilde{}e^{-i(\omega t-kr)}$ the characteristic equation system must be analyzed

$$\left(k_z^2-\frac{4\pi i\omega}{c^2}\sigma_{xx}\right)E_x+\left(-\frac{4\pi i\omega}{c^2}\sigma_{xy}\right)E_y-\frac{4\pi i\omega}{c^2}\sigma_{xz}E_z=0$$
$$\frac{4\pi i\omega}{c^2}\sigma_{xy}E_x+\left(k_z^2-\frac{4\pi i\omega}{c^2}\sigma_{yy}\right)E_y+\left(-\frac{4\pi i\omega}{c^2}\sigma_{yz}\right)E_z=0$$
$$\frac{4\pi i\omega}{c^2}\sigma_{xz}E_x+\left(-\frac{4\pi i\omega}{c^2}\sigma_{yz}\right)E_y+\left(-\frac{4\pi i\omega}{c^2}\sigma_{zz}\right)E_z=0$$

Here x-direction of the orthogonal coordinate system coincides with the direction of openness for iso-energetic surface. Wave vector direction k coincides with z-direction, Larmor frequency is much higher of wave frequency and of reversal relaxation time. The solution of mentioned equation system shows that wave vector can be represented as $k_z^2=\left(4\pi i\omega/c^2\right)\sigma_{xx}$. So the existence of wave similar to helicon geometry is impossible on the reason of complexity of wave vector. When a magnetic field will be oriented non-orthogonally strictly there is a chance to excite the helicon type wave having ellipsoidal polarization.

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Part II
Interaction of electromagnetic field with structure particles

Fedorov's covariant approach and the development of particle physics in Belarus

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The basic properties of the worked out by F.I.Fedorov general covariant approach for solving the problems in the particle physics are outlined. The main results obtained by Belarusian physicists in the framework of this approach are briefly reviewed.

Hadronic spin polarizabilities (gyrations) in the relativistic quantum field theory

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We analyze polarized Compton scattering which provides information on the structure of hadrons. On the basis of the correspondence principle between the relativistic moving medium electrodynamics and relativistic quantum field theory the covariant Lagrangian of the electromagnetic field interaction with the polarized spin particles have been obtained. This Lagrangian contains four independent covariant spin polarizabilities. These polarizabilities are related to the spin structure of the hadron at low energies and are structure-constants of the Compton scattering amplitude. The Lagrangian is shown to satisfy the main relativistic quantum field theory requirements and can be used for description of two-photon processes on hadrons.

Static electric polarizability of π-meson in the Poincare' covariant quark model with scalar quarks

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The static electric polarizability of a π-meson is obtained by means of the relativistic equation of two-particle scalar quark system with Cornell potential.

The paper presents the limitations to the masses of u, d quarks and parameters of the interquark potential by means of the oscillator model function of a π-meson state, following from the experimental values of the electric polarizability of a π-meson.

In paper we have performed the analysis of the possible consistent description of the electric polarizability, form-factor and the lepton constant of a π-meson.

Radiative corrections and new–physics searches at e^+e^- colliders

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For the processes $e^+e^- \to \mu^+\mu^-, b\bar{b}$ and $c\bar{c}$ at a future e^+e^- linear collider (LC) we examine the role of the photonic corrections on the sensitivity of the helicity cross sections to four-fermion contact interactions. The observed cross sections is signicantly distored in shape and magnitude by the emission of real photons by the incoming electrons and positrons. In particular, due to the radiative return to the Z resonance at $\sqrt{s} > M_Z$, the energy spectrum of the radiated photons is peaked around $k_{\rm peak} \approx 1 - M_Z^2/s$. In order to increase the signal originating from contact interactions we impose the cuts on the kinematical parameters to eliminate the events with hard photons.

Experimental status of dipole and spin polarizabilities of nucleons

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Recent progress in experimental study of the dipole and spin polarizabilities of nucleons is discussed. It is noted that the dipole proton polarizabilities have been successfully found in a series of experiments on γp scattering which yielded quite an accurate result $\bar{\alpha}_p =$

$12.1 \pm 0.8 \pm 0.5$, $\bar{\beta}_p = 2.1 \mp 0.8 \mp 0.5$ in the units of 10^{-4} fm^3. This result found a confirmation in a Mainz experiment on Compton scattering off the quasi-free proton in a deuteron target. Disagreement between different measurements of the backward spin polarizability of the proton is demonstrated. Three possible methods to determine the neutron polarizabilities are also discussed. These are experiments on scattering of low energy neutrons in electric fields of heavy nuclei and on Compton scattering off both free and quasi-free neutrons. An analysis of obtained results is given.

Electromagnetic characteristics of hadrons in the diagram-quark approach

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We have determined low-energy electromagnetic characteristics of two-quark hadrons by construction of effective action functions of interaction of an electromagnetic field with hadrons on the basis of general principles of an electrodynamics of solid media and quantum field theory. Within the framework of a formalism of a functional integration the diagram-quark method of calculation of these characteristics of hadrons for the determinate models of potential interactions between quarks is offered.

One-photon exchange quasipotential matrix for a system of e^- and N-scalar particles

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A system of one spinor and several scalar particles is considered in framework of the covariant single-time approach of quantum field theory.

The double-time Green function matrix is built in the second order of perturbation theory, without projection on positive-energy states and using α-gauge form of the photon propagator. It is also found an explicit form of all the components of quasipotential matrix, corresponding to one-photon exchanges.

The parametrical dependence of quasipotential matrix on the full energy of the system and the energy-dependent normalization condition for a bound-state wave function are obtained and analysed.

As an example we discuss the three-body system, consisting of α-particle, π^--meson and e^-, which is some exotic helium atom.

Radiative decay form-factor of a pseudoscalar quark-antiquark bound-state

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The radiative decay of pseudoscalar quark-antiquark bound-state into two virtual γ-quantae is considered in framework of the covariant single-time approach of quantum field theory.

The commom integral form of decay form-factor, depending on a relativistic wave function of the bound-state, is found.

Also, the explicit form of decay form-factor and its dependence on the full energy of the system are obtained and analysed, using the model wave function with correct asymptotic behaviour.

As an example of mentioned bound-state, the light unflavoured meson is discussed. The case of decay into two real γ-quantae is considered too.

Expansion on plane waves and integral transformations between $\vec{x}-$ and $\vec{r}-$ representations

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Two methods of expansion of a quantum system wave function given in momentum representation on plane waves are considered:

a) the expansion on nonrelativistic plane waves $exp(i\vec{p}\vec{x})$,

b) the expansion on relativistic plane waves $\xi(\vec{r},\vec{p}) = ((p_0 - \vec{p}\vec{n})/m)^{-1-imr}$ [1].

Formulas connecting wave functions in $\overrightarrow{x}-$ and $\overrightarrow{r}-$ representations are discussed.

The partial expansion of all magnitudes of the approach is performed. As a result an explicit form of direct and inverse integral transformations for partial wave functions is found. The kernels of these transformations are expressed in terms of McDonald functions and Γ - functions.

It is shown, that the obtained integral transformations are some generalizations of direct and inverse Kontorovich-Lebedev transformations.

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Point form relativistic Hamiltonian dynamics and pion charge radius

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The analytic expressions for the mean square radius of a π-meson are obtained by means of various model wave functions within the Poincare covariant quark model based on of the point form relativistic Hamiltonian dynamics.

The paper shows that the correspondence between experimental and theoretical values of a π-meson can be achieved by introducing a quark form-factor. Moreover, the momentum given to the quark is not equal to the one given to the π-meson.

The values of the mean square radius of a quark for various model wave functions are obtained by means of the dipole dependence of the quark form-factor on the transferred momentum.

Spin effects of the W-production in hadron-hadron collisions

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The spin crisis induced a number of new experiment and theoretical activities to investigate in more details the spin structure of the nucleon. However, now the question of how the spin of the nucleon is composed of its elementary constituents remains open. Purely inclusive measurements determining the longitudinal spin structure functions $g_1(x, Q^2)$ for nucleons and deuteron are unfortunately restricted to probe only certain combinations of the polarized parton contributions to the nucleon spin. A

full analysis would require additional inputs from other measurements to separate the different components.

In this paper we are concerned with experiments which may provide direct measurements of new independent combination of the quark densities in polarized nucleon. We will focus on inclusive single W-boson production in hadron-hadron interactions with one longitudinally polarized beam $N + \vec{N} \to W^{\pm} + X \to l^{\pm} + X$, when in the final state only charged lepton is detected.

In our presentation we get formulas, which connect the polarized quark densities in the region of small x with the observable single asymmetries of this process, combination of unpolarized quarks densities and polarized quark densities in the region where they are well defined. The equations allow to determine the low-x behavior of polarized u- and d-quark and antiquark distributions in nucleon.

Static electrical polarizability of a π meson in a composite scalar quark model in the quasi-potential approach

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In the present paper in a formalism of a single-time approximation we obtain the quasi-potenzial equation for a "positively - frequency" wave function of a neutral system of two scalar charged particles of an equal mass in an external electromagnetic field in the second order on this field. Because of sectional equation the shift of levels of an energy of a system in an external field is defined. The calculation of an electrical polarizability for a pi meson in composite scalar quark model with Coulomb and with oscillating potentials is produced. The theoretical analysis of numerical estimations of static polarizabilities of a composite system is carried out.

Section D
Acoustooptics

The solution of direct optoacoustic problem for one-dimensional thermally non-conductive media

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Nondestructive evaluation of optical, thermophysical and acoustical properties of spatial inhomogeneous media is important problem from both fundamental and applied standpoints. The optoacoustic (OA) method based on laser thermooptical excitation of ultrasonic (OA signal) in absorbing media and wide band registration of signal, can be highlighted from among existent methods. For some condition of laser pulse duration and thermally non-conductive media, for example biological tissue, the OA signal form replicates the spatial distribution of the thermal sources in the medium. The solution of inverse problem of spatial sources distribution inside investigated media from the measured OA signal is more important but it intends the solution of direct problem. In this work the method of numerical calculation of frequency transfer function and temporal pressure profile of OA signal are considered. The one-dimensional layered medium with known physical properties of each layer was investigated. As the changes of acoustical and thermophysical properties of biological tissue are noticeably less than the changes of absorption coefficient, so the medium in our model is acoustically and thermophysically homogeneous. At first we solved the problem of spatial distribution of sources, then we calculated the distribution of temperature fields, and finally the acoustical response (the frequency transnsfer function) caused by thermal expansion of medium was obtained. The temporal profile of OA signal was obtained by means of backward Fourier transformation. We hope that this method will be useful for the solution of inverse problem of OA tomography.

Amplitude and phase peculiarities of the acoustooptical interaction in chiral media

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A study of light diffraction from ultrasonic waves in anisotropic chiral crystals is of practical interest, because a number of promising crystals such as paratellurite (TeO_2), tellurium (Te), and bismuth germanate ($Bi_{12}GeO_{20}$) possess a significant specific rotation of the polarization plane of the light wave. In [1,2] polarization and energy parameters of diffracted waves were investigated in detail in a nonchiral isotropic medium in the Bragg and intermediate regimes of the acoustooptical (AO) interaction. In this paper we studied polarization and energy properties of light waves dependent on amplitude and phase peculiarities of the AO interaction for Bragg and the intermediate diffraction regimes. For this regimes of diffraction the assymmetry of the diffraction pattern and chirality give rise to an additional phase shift in diffracted waves and as a result the polarization of light at the output of the AO interaction region turns out to be elliptical in the general case. It can be said that in the chiral medium there appear two coupled phase diffraction gratings moving along the ultrasonic wave velocity. For the s- or p- polarized incident light waves there is dependence of the diffracted wave amplitudes on a phase of their s- and p- polarized components. The features of polarization effects is explained by a considerable change in the phase difference of s- and p- polarized components of the diffracted waves and the ratio of their amplitudes.

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Optical nonreciprocity at collinear acousto-optic interaction in chiral cubic crystals

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In this paper the features of collinear acousto-optical interaction in not centrosymmetric cubic crystals with an electroinduced anisotropy had been investigated. Is has been shown, that such interaction is accompanied by nonreciprocal effects, which one can be used for obtaining the regime of unidirectional and single-frequency laser oscillation. It has been established the dependence of value of amplitude nonreciprocity dI on a propagation direction both polarized light and ultrasonic waves, and also on orientation of an external electric field. The maximum value of dI will be achieved, when the wave vectors of ultrasonic and light waves are collinear to the direction [110], the external electrical field is oriented along the axis [010], and the ultrasonic wave is polarized collinear to [111]. The capability of switching of direction of generation of a circular ring laser by means of changing the direction of controlling field has been found. The results of the paper can be applied for development and optimization of parameters of electro- and polarizable controlled acousto-optical nonreciprocal element on the basis of cubic chiral crystals.

Picosecond ultrasonic study of Au/V multilayers

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A picosecond ultrasonic study of Au/V superllaticess in period between 60-120 *Angström* been performed. Au/V structures were grown by molecular beam epitaxy (MBE) on MgO substrate. High frequency ultrasonic vibrations of Au/V structures were genereted by using ultrasort laser pulse excitation and detected in real time by measuring the strain induced change in reflectivity with pump-probe technique. High frequency oscillations were detected over the first 150 ps. Period of the oscilations was proportional to the superperiod of the multilayers. The oscilations were generated when terminated layers is made of the material with the lowest acoustic impedance (vanadium for Au/V multilyers). We attribute these oscillations to surface mode localized in frequency band gap of the dispersion curve.

Photothermoacoustic effect in solids: the role of stressed state

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The problem of control and visualization of the elastic stress fields distribution is of great importance for the present-day materials research. This is connected with modern technologies' demands for new materials or composites made on their base. Conventional methods of the residual stress determination are very tedious and thus are not widely used in material testing techniques. In some of the recently published works [1,2] the stressed state of material is studied by a photoacoustic (PA) method. This paper presents the results on photoacoustic (PA) method for detection of the stressed state of a substance. Theoretical and experimental researches that were carried out, make it possible to confirm that PA signal formation in stressed region of the medium depends on the nonlinearity of elastic and thermoelastic constants. The peculiarities of PA signal formation in samples with real residual stress distribution were studied theoretically and experimentally. The mechanism PA signal formation in the stressed area of substance was proposed.

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Photothermoacoustic microscopy: the nature of thermal wave's visualization of epitaxial and ion-implanted regions in Si structures

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It is well known that in semiconductors under irradiation with modulated light, electron - hole plasma waves are exited in line with heat waves. This causes redistribution of volume heat sources and, as a consequence, changes the temperature dependence on generation-and-recombination parameters of semiconductors.

Previously [1] the comparative investigations on photothermoacoustic microscopy (PA) and microscopy for alternative photo - e.m.f. detection in near-surface layers of semiconductor structures (PE microscopy) have been carried out. The experiments show that the additional information on semiconductor structures properties can be obtained by simultaneous using of these methods.

The present work is devoted to study of some of the Si-based structures by means of combined photothermoacoustic (PA) and photoelectric (PE) microscopy technique ($f_m = 80kHz$, laser beam spot diameter <10 μm).

The following samples were studied:

-p-Si plates having a n-type region of epitaxial growth ("*pocket*");

-p-Si plates with non-doped/doped material interface (ion-beam implantation of B^+ with a dose of 0.05 $\mu K/cm^2$).

Conclusion is made that the most probable cause of the thermal-wave visualization of epitaxial regions is elastic stresses arising in these regions during a production process. It is shown that spatial distribution of the elastic stresses arisen during the ion-beam implantation is visualized by thermal waves.

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Laser photodeflection spectroscopy of the spatially non-homogeneous media

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An important and long-range direction in the development of modern systems of diagnostics and non-destructive control is working out of ways of non-contact, distant registration of mechanic strengths and defects appearing in the volume of solids. A series of methods is used for the solution of problems of such a type of complexity, among which it is necessary to single out ultrasound spectroscopy, methods of holographic interferometry and diffraction methods. Photothermal methods of investigation of condensed media have been widely used recently [1]. A distinctive peculiarity of photothermal methods used for studying solid objects is their universality and relative simplicity of measurement realization. One of the photothermal methods is the method of photodeflection spectroscopy [2], which is also successfully applied in the study of chiral media [3]. This paper theoretically investigates the process of the photodeflection response formation in the sample possessing non-homogeneities of the inner structure. The influence of subspatial defects on the amplitude and phase characteristics of the photodeflection response has been studied on the basis of analytical expressions, obtained by the authors for the description of processes of photothermal transformation in the volume of the media. It was shown that non- homogeneities of the inner structure of the investigated substance make a considerable contribution to the processes accompanying photothermal transformation of energy. As a result the characteristics of the photodeflection response of the sample possessing non-homogeneities of the inner structure change. The paper shows the possibility of using the method of photodeflection spectroscopy for detecting and visualizing defects and local non-homogeneities of the inner structure of the substance. There has been carried out a comparative analysis of the accuracy of information about inner defects of a non-homogeneous object during photodeflection and photoacoustic ways of registration of the resulting signal.

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Thermooptic excitation of ultrasonic waves in absorbing magnetoactive medium

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As is known the spectral transfer functions allow to determine dissipation and thermophysics constant of medium if on a spectrum intensity of laser radiation and experimentally measured amplitude of a photoacoustic signal are given.

In this paper the transfer functions are obtained for absorbing magnetoactive medium in registration multibeam interference of optical waves and thermal fluxes for cases of free and fixed boundaries.

The analysis of dependences of modules of transfer functions on frequency of a ultrasonic wave for the right- and lefthanded circularly polarized stimulating radiation is carried out. If $\omega < \alpha_{\pm} \cdot c_0$ ($\alpha_{\pm}$ - factor of absorption , c_0-adiabatic speed of a ultrasonic in medium), the excitation of a ultrasonic occurs more effectively at the fixed boundary surface. In field $\omega > \alpha_{\pm} \cdot c_0$ the generation of ultrasonic waves is more effective at a free surface. An effectively raised rangefrequencies in case of free boundary of absorbing medium is more than two times wider, than at the fixed boundary.

The dependences of modules of transfer functions on thickness of a sample are also obtained in the paper. It is shown, that on small depth the excitation of a ultrasonic is more effective at free boundary of absorbing medium, and with an increase of depth the signal grows for the fixed boundary. Thus for the fixed boundary surface there is field of absorbing due to fact that length of optical absorption becomes more than length of thermal diffusion in a sample.

An investigaton of the phototermoacoustic effect for the solid-pyroelectric sensor structure

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The theoretical and experimental investigation for the phototermoacoustic effect in a solid was completed and the thermal waves were registered with the pyro-sensor. The "object - sensor" structure is simulated like a thin plate. The sensor consists of two identical layers. The voltages and phase differences between the sensorTs layers, which were registered for the sensor, were calculated also for modulation light frequency dependence and the structure parameters. An analysis of expressions which was obtained for different parameters showed that the amplitude-frequency and phase-frequency dependence of the phototermoacoustic signal is more sensitive with the structure's parameters near low-range frequencies of the modulation. The conditions for the determination for some elastic and thermal parameters were evaluated. The experiments were done for Zn, Cu and CTS. Registration of the photo- acoustical signal was produced by two - layered CTS maked sensor of the thickness equal to 2.06 mm. The sample and the sensor have the shape of disk with the 15 mm diameter. The frequency range was 9-1000 Hz. The normal Young modulus and the thermal diffusion coefficient were evaluated for the sample. These data incouple with the theoretical solution allow we to calculate amplitude- frequency and phase- frequency expressions which are in good agreement with the experimental data.

Acoustooptical properties of superlattices

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In the long-wave approximation it has been obtained analitical expression for determination of effextive photoelastic parameters p_{ij}^e of superlattice (SL) formed by crystalline layers of arbitrary symmetry. It has been shown that in general case values of p_{ij}^e are determined by photoelastic constants of SL components and correlation between their thicknesses. It has been found that by disorientation of crystallographic axes X_3 of layers the symmetry of effective medium decreases. It may display in the changes of effectiveness of light diffraction and appearance of acoustooptic interactions forbidden by symmetry of SL components. It has been found that by determined correlation between layer thicknesses it is possible to forbid the diffraction of light on ultrasound in geometry of interaction for which diffraction takes place in the case of crystals formed the periodic structure.

On the base of obtained analytical expressions the photoelastic constants for widely used superlattices have been calculated.

Results of paper may be used by creation of highly-effective acoustooptical systems on the base of polycristalline materials and optimization of their parameters.

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Elastic and acoustooptical properties of Cs_2HgCl_4 crystals

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In accordance with our previous investigations [1] the elastic properties of Cs_2HgCl_4 crystals are characterised by rather low magnitudes of ultrasonic velocities for both transverse and longitudinal waves, which appear in the range between 800 and 2000 m/s. This allows us to predict relatively high values of main acoustooptical parameters of this material, such as acoustooptical quality and diffraction angle which is important in many applications. We report here new results concerning the investigations the photoelastic and acoustooptical properties of Cs_2HgCl_4 crystals.

The deviation angle between the phase and group velocities for the ultrasonic waves in the XY, XZ, YZ - planes has been calculated using the elastic constant tensor determined from previous ultrasonic measurements [2]. It was found that deviation angle for such cases did not exceed even 5°.

Applying the polarising interferometer we have determined all components of the piezooptical tensor for Cs_2HgCl_4 crystals at room temperature. At the beginning the principal components of the piezooptical effect tensor have been measured on the direct-cut sample. And then the values of π_{44}, π_{55}, π_{66} coefficients have been calculated on the basis of two-stage measurements method on the 45° - cut sample. For spatial anisotropy analysis of the piezooptical effect at first the indicative surfaces and their stereographic projections for longitudinal and transverse components of piezooptical tensor of the Cs_2HgCl_4 crystals have been constructed on the basis of created software.

Using the results of our measurement of the all elastic and piezooptical coefficients the corresponding elastooptical coefficients matrix were subsequently estimated. Such estimations give the following values for the components of the elastooptical tensor: $p_{11} = 0.40$, $p_{12} = 0.40$, $p_{13} = 0.39$, $p_{21} = 0.26$, $p_{22} = 0.29$, $p_{23} = 0.34$, $p_{31} = 0.17$, $p_{32} = 0.19$, $p_{33} = 0.25$, $p_{44} = -0.034$, $p_{55} = -0.026$, $p_{66} = -0.032$. The acoustooptical quality M_i parameter calculated for the principal directions of the interaction between optical and acoustic waves can be characterised as sufficiently high (for some cases $M_i > 100 \cdot 10^{-15}\ s^3/kg$).

On the basis of these investigations we testify the possibilities of usage Cs_2HgCl_4 crystals as a perspective acoustooptical material.

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Incommensurate phase in $TlInS_2$ crystals: transformation features studied with acoustic methods

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Different acoustic methods are successfully used to study the phase transitions (PT) in solids and liquids. The acoustic emission method is quite informative for investigation of PT that are connected with an incommensurate phase formation. We have studied experimentally the features of incommensurate phase appearance and disappearance in ferroelectric crystals $TlInS_2$. The temperature dependencies of longitudinal ultrasonic waves absorption coefficient α(T) and acoustic emission intensity N(T) at the temperature range T=100...300 K were obtained. It was found that the processes of incommensurate phase appearance and disappearance in $TlInS_2$ crystals cause the significant maxima on α(T) and N(T) dependencies. The "gigantic" temperature hysteresis (ΔT >

25 K) for "commensurate-incommensurate" PT also was found out. We have shown, that repeated continuous thermocycling of $TlInS_2$ samples at the range T=100...300 K leads to significant changes of incommensurate phase parameters and its temperature interval of existence. The similar results we have found for $TlGaSe_2$ crystals earlier. Acoustic experimental results were analyzed based on the comparison with $TlInS_2$ crystals structure data, obtained with X- ray experiments in the same temperature range.

Acoustic emission at absorption of elastic waves in monocrystals LiF

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In the reference [1-4] there is understanding of an acoustic emission (AE) as radiation of ultrasonic random pulsing waves by local areas of solid termed as AE-sources. Process of radiation of AE by these local areas guesses the energy liberation a s a result of change of local residual stresses and strains. This effect guesses nonreversibility of process of radiation and small probability of recurring of radiation of an impulse of AE by the same AE-source. Actually radiation of AE is especially individual process for each local volume, which has the natural characteristic size and level of residual stresses. At propagation through a sample of a ultrasonic wave in a fixed instant of time on distances $\lambda/2$ there can be rather considerable gradient of additional stresses. Thus the mean strains of a solid remain inappreciable (area of elastic strain). In this connection the comparison of dependencies of AE of a crystal deformed by ultrasound and an amplitude-dependent absorption of this ultrasound is interesting. Taking into account nonreversibility of process of AE these dependencies were measured simultaneously. For used samples LiF and

frequencies of longitudinal ultrasonic wave 10 - 35 MHz the sizes of local areas were 100-350 microns. The dependencies of amplitude of AE-signals and the amplitudes of transmitted ultrasound on amplitude of ultrasound creating stress in a crystal have similar nonmonotoneous dependencies. Ther is a qualitative congruence between local minimums of amplitude of transmitted through a sample ultrasound and maximums of amplitude of AE. Thus, the magnification of amplitude of AE is caused by magnification of absorption of ultrasound.

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The diffraction of Bessel's light beams on ultrasonic waves

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At present Bessel's light beams (BLB) are intensively investigated in optics. The specific feature of BLB is that a spatially confined BLB is characterized by an 'elongated' focus, i.e. by a suppressed diffraction divergence of the central part of the beam. These properties allow to use

a constant profile of a center BLB for longitudinal - homogeneous action of a radiation on substance and for a realization of nonlinear interactions. Besides the investigation of transformation of BLB in parametrical processes inside of optically anisotropic crystals is of interest. In the paper the interaction of BLB and the plane ultrasonic wave at the collinear interaction inside of the anisotropic crystal was investigated. The system of equations is obtained which describes process of acoustooptical diffraction. The effectiveness of a diffraction is calculated, also the dependence of diffraction effectiveness on number of diffracted modes is investigated. Is shown, that the diffracted BLB has orthogonal polarization and a conicity angle smaller, than at incident BLB. The possibility of using of the given type of interaction in acoustical filters is analysed.

Acoustooptical interaction of Bessel light beams

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The development of optics of Bessel's light beams (BLB) reduces to necessity of investigation of their transformation in processes acoustooptical (AO) interactions. In the present paper the collinear AO diffraction of BLB on the Bessel's acoustic beam (BAB) is considered. The system of equations which describes process of AO diffraction is obtained. The dependence the AO diffraction effectiveness on number of modes of BLB is found. In paper scalar and vectorial interactions of beams are considered. The angular width of a synchronism at AO interaction is defined. Is shown, that the distribution of intensity diffracted BLB in distant zone represents a ring. If the diameter of a ring of diffracted BLB is equal to a diameter of incident BLB, this case corresponds to scalar interaction of beams. The ring of a smaller diameter of diffracted BLB corresponds to vectorial interactions of beams. The possibility of using of the given type of interaction in AO filters is analysed.

Control by a focussing of light beams at quasi-resonance acousto-optical interaction

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The nonresonance interaction of a light field with a ultrasonic wave reduces, as is known, to phase modulation of a wavefront of a light wave. Besides modification of a phase surface of a light field can appear. It excites effects of a focussing and undiffractional propagation of light beams. In the present paper the effects of undiffractional propagation and focussing of light beams are investigated in details at quasi-resonance diffraction on a ultrasonic wave in approximation of constant intensity. Acoustooptical focusing device on the base of crystal TeO_2 is analytically and numerically are investigated The conditions of a focussing, focal length, angular aperture of a lens are found at acoustooptical interaction. The possibility of reorganization of it parameters with the help of reorganizations of frequency of ultrasonic wave is shown.

Secondary electrooptical effect in superlattices

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Due to successes by creation of superlattice (SL) research of propagation of electromagnetic waves in such media is of great interest. Application of SL allows to combine useful properties of component of SL and also to expand functionality of devices due to the phenomena, impossible in monocrystals. The most general approach for research the light transformation in SL is to solve Maxwell equations and to take into account conditions on boundaries of layers. But thus, in most cases there is possible only a numerical analysis of processes.

In this paper we assume that the length of a light wave considerably exceeds the period of SL and therefore the phenomena of diffraction on boundaries of layers can be neglected. Then we may use the long-wave approach. Electrooptical properties of such structures are considered and secondary electrooptical effect (SEOE) is taken into account.

As a result the dependence of effective electrooptical parameters of medium on a ratio of thickness, an angle of disorientation of crystallographic axes of a superlattice and strength of an external electric field are obtained.

The following is found:

1) Presence SEOE results in disappearance of electrooptical interaction at the certain ratio of thicknesses of SL components.

2) Electrooptical parameters may change a sign and considerable differ from values without SEOE taking into account.

Thus, it is important to consider SEOE at creation of SL and research of propagation of electromagnetic waves in SL.

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