JPRS Report

Science & Technology

USSR: Physics & Mathematics

DTIC QUALITY INSPECTED 8

19990305 049

Science & Technology
USSR: Physics & Mathematics

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UDC 532.23

Structure of Turbulent Mixing Zone at Gas-Gas Boundary Accelerated by Shock Waves

[Article by Ye.Ye. Meshkov, V.V. Nikiforov, and A.I. Tolshmyakov, Moscow]

[Abstract] An experimental study was conducted concerning the turbulent mixing zone at the boundary between two gases of different densities, this boundary being accelerated by successive steady shock waves in a wind tunnel. Shock waves were passed through a channel consisting of three compartments in a row each with transparent lateral walls. Two thin organic film, each having a specific mass of 30-40 gm/cm^2, their planes perpendicular to the direction of shock wave propagation, separated the middle compartment containing air with tobacco smoke from both the first compartment containing pure air and the last compartment containing helium. The exit from that 169 mm long last compartment was closed with a stopper made of acrylic glass and acting as a rigid wall. The film separating air with smoke from air with helium was accelerated by shock waves propagating at a velocity of Mach M = 1.3, accelerated and decelerated by shock waves, returning after reflection by the rigid stopper. The turbulent mixing zone forming at the air-helium boundary was observed visually and photographed, a light beam emitted by a laser in pulses of 40 ns duration transformed by cylindrical lenses into a knife edge of light and the latter passed through the transparent rigid stopper into the channel. Smoke particles present in the air, and so small as to virtually adhere to it, scattered the light forming an image of the smoke pattern and also of the air density distribution in the mixing zone. A densitometric wedge was simultaneously photographed for reference, a part of the laser beam having been diverted by a semitransparent plane mirror into a Ragulskiy wedge formed by another semitransparent, opaque plane mirror. The speckle structure of the image was eliminated by a scattering filter of milk glass. The photographs have been processed so as to reveal the air density distribution on the basis of light intensity distribution. The results are analyzed and interpreted from the standpoint of gas flow theory, air containing smoke being treated as a two-phase gaseous medium. The adaptability of its particles to prevailing conditions is characterized by a parameter which has the dimension of length and has been introduced as a new criterion in addition to the Reynolds number. Figures 5; references 8.

UDC 533.6.011.72

Interaction of Spherical Shock Waves and Thermal Gas Inhomogeneities Near Surface

[Article by V.A. Andrushchenko and M.V. Meshcheryakov, Moscow]

[Abstract] Interaction of spherical shock waves generated during optical breakdown with thermal gas inhomogeneities produced by the external radiation source is analyzed in the two-dimensional axisymmetric approximation, considering that a laser-induced breakdown occurs at some given altitude H above a thermally insulated rigid plane surface. The corresponding system of Navier-Stokes equations in dimensionless gas variables and cylindrical coordinates are solved for three different boundary-value problems, the first one involving a homogeneous thermal layer of uniform thickness h' on the surface. The second problem involves a homogeneous cold layer of uniform thickness h' on the surface. The third problem involves a circular layer of gas within the range of the laser beam and uniformly heated by the latter at an altitude h' above the surface. The system of Navier-Stokes partial differential equations is replaced with an approximating system of difference equations, the latter being split with respect to coordinates and functions according to an implicit scheme of second-order accuracy which has been stabilized by damping. Calculations were made on a Standard System 1055 computer, using a 201 x 61 grid. Analysis of the interaction based on numerical solution for seven sets of initial conditions reveals that a thermal gas layer, having a discontinuous upper boundary, splits a reflected shock wave into one which proceeds toward the primary heat source and one which returns to the epicenter. The substrate surface in this case reflects shock waves in the regular mode when their angle of incidence is small or in the Mach mode as the critical angle is reached and exceeded. A cold gas layer decelerates incident shock waves and delays the transition from regular to Mach reflection. A shock wave entering a circular hot gas layer above the surface splits into one which continues propagating in the same direction and a rarefaction wave which moves in the opposite direction. This gives rise to a buildup of a rather large low-pressure region along the vertical axis of symmetry, the denser gas around and above that layer eventually rushing toward that axis and generating a secondary shock wave of cumulative origin. Figures 5; tables 2; references 12.

UDC 539.2

Dynamic Structures of Dislocation Dipoles Formed by Ultrasonic Action

[Article by N.A. Tyapunina, A.L. Lomakin, and Kh. Khristu, Moscow State University imeni M.V. Lomonosov, Moscow]

[Abstract] Structural changes in solids effected by periodic action of ultrasound, specifically translatory movements of dislocations, are analyzed theoretically on the basis of computer experiments, a laboratory study of this process not being feasible. As model has been selected a

dipole of infinitely long straight edge dislocations parallel to the OZ axis with a Burgers vector along the OX axis moving in the XZ plane of easy slip. The equation of motion in the quasi-viscous and non-inertial approximation, valid at kilohertz frequencies, includes a term representing movement of dislocations dependent on both amplitude and frequency of the ultrasound and a term representing movement of dislocations due to their interaction. The latter term appears as the sum of all interaction forces F^{ij} (i not equal to j) minus the threshold or starting force, those forces varying in space and in time as the distance between dislocations varies. The computer experiments reveal various possible complex patterns of dislocation behavior and resulting dynamic dipole structures under an ultrasonic load, quite different from those under a static load and only a weak ultrasound of small amplitude causing each dislocation to oscillate about its stable static equilibrium position. Figures 4; references 7.

Development of Optical Breakdown in Shock-Compressed Air

[Article by A.P. Budnik, S.G. Popov]

[Abstract] Development of optical breakdown in air compressed and heated by a shock wave is analyzed, considering a typical situation in which incident radiation of gigawatt/cm^2 intensity from a CO_2 laser causes supercritical explosion of water aerosol droplets up to 20 μm in diameter. Within the shock wave, which is generated around an exploding droplet, the temperature can reach 4000-5000 K and the pressure can reach 100 atm, the maximum compression being maximum when the process is adiabatic and reached within 10 ns. As both temperature and pressure subsequently drop, the residual heat facilitates buildup of an electron avalanche over a period of about 50 ns. Inasmuch as initiation of optical breakdown of water aerosol in air requires CO_2 laser pulses of about 100 ns duration. A numerical simulation of water droplet and laser pulse interaction indicates that plasmochemical reactions in air can produce an appreciably initial ionization of air, up to an order of 10^{10}cm^{-3} electron concentration. The principal reactions within the 3000-5000 K temperature range are the seven reversible ones $O_2 + M = O + O + M$, $N_2 + M = N + N + M$, $NO + M = N + O + M$, $N + O_2 = NO + O$, $N_2 + O = NO + N$, $N_2 + O_2 = 2NO$, and $NO^+ + e = N + O$ (M-denoting a participating neutral atom or molecule). The change of concentration of the seven air components (N_2, O_2, N, O, NO, NO^+, e) is described by a system of seven nonlinear equations of kinetics involving seven reaction rate constants, assuming that the air density and temperature behind the shock wavefront remain constant. Development of an electron avalanche is accounted for by adding the two reactions $N_2 + e \rightarrow N_2^- + 2e$ and $O_2 + e \rightarrow O_2^- + 2e$ with the corresponding reaction rate constants. A numerical solution of this system has yielded the temperature-time dependence of electron concentration and the rate constants of all seven forward and seven reverse reactions behind the shock wavefront in hot air after optical breakdown. Figures 1; tables 1; references 4.

Evolution of Shock Waves and Duration of Phase Transition Process in Armco Iron

[Article by B.I. Gromov, M.V. Yerofeyev, A.A. Kalin, and V.A. Moiseyev]

[Abstract] An experimental metallographic study of ε and $\varepsilon \rightarrow \alpha$ phase transitions induced by laser shock-wave pulses in Armco iron was made, α being the b.c.c. phase and ε being the c.p.h. phase. The target consisting of grains within the 150-300 μm size fraction was treated with laser pulses of 3 ns and 23 ns duration at the 50 percent level, with the power density varied up to 5 x 10^{12} W/cm^2 corresponding to 115-140 GPa pressure on the target surface under the front of a shock wave. The evolution of the shock-wave amplitude profile over the target thickness was traced in terms of a hydrodynamic model which had been pretested on compression-wave amplitude and duration. The duration of a shock-wave pulse was estimated from the dimensions of twins in the target and from the thickness of a lamella split off during one fracture. In specimens treated with laser pulses of 3 ns duration a correlation was established between the dimensions of twins and their distance from the surface under such a heat load. Phase transition was identified, after etching, by a change of color to a darker one and by an abrupt change in microhardness by a factor of about 3 at the interphase boundary, such a large change being characteristic of phase transition in Armco iron. An analysis of the data revealed no phase transition in Armco iron upon incidence of 3 ns laser pulses and a $\varepsilon \rightarrow \alpha$ phase transition in Armco iron upon incidence of 23 ns laser pulses. The transition time in either direction, on the basis of numerical calculations, does depend on the amplitude of laser shock waves but is much shorter than had been previously estimated. Figures 2; references 12.

Characteristics of Nonaxisymmetrc Ejections From Superhigh-Speed Impact Craters

[Article by E. M. Drobyshevskiy, B. G. Zhukov, S. I. Rozov, V. M. Sokolov, R. O. Kurakin, M. A. Savelyev, Engineering Physics Institute imeni A. F. Ioffe at the USSR Academy of Sciences, Leningrad]

[Abstract] The dynamics of three-dimensional ejections from explosion and high-speed impact craters are not well-known, although such phenomena occur often and their practical importance is beyond doubt (excavating explosions, oblique collisions, impact of large meteorites, etc). Certain characteristics of the superhigh-speed interaction of cubic strikers with the plane bounding a half-space (actually, with the end of a long D-16 dur-alumin cylinder with a 13 cm diameter) are examined. A polycarbonate cube with a 10-12 mm side and a 1-2 g mass was accelerated in an electrodynamic accelerator to a 4-5.5 km/s velocity, so that its kinetic energy greatly exceeded the molecular binding energy. During the impact it vaporized together with a part of the target matter. A corona formed at the moment of impact. The nonaxisymmetric ejections from the target during various types of impact were recorded on film with a 4 μs frame spacing and a 1 μs exposure and the patterns of the ejection shape as a function of the impact angle were analyzed. References 4: 2 Russian, 2 Western; figures 2.

Diamagnetism of Nonequilibrium Semiconductor Plasma

[Article by V. N. Podshivalov, V. V. Masalov, V. I. Makhov]

[Abstract] Equilibrium solid state plasma does not possess any magnetic properties. Magnetism of nonequilibrium solid state plasma has not yet been described. The results of an experimental observation of solid state plasma diamagnetism caused by the effect of infrared radiation on indium antimonide are presented. An n-type InSb plate was placed in a copper wire coil and illuminated by a light-emitting diode with a peak at a wavelength of about 0.9 μm. Measurements were taken at 77K. The alternating voltage amplitude on the coil terminals was measured during the semiconductor plate exposure to frequency-modulated infrared radiation within 40-60 kHz. In addition, the effect of the magnetic induction vector direction on the output signal phase was measured at the resonance frequency. As a result of the experiments, diamagnetism in nonequilibrium solid state plasma under the effect of luminous radiation was demonstrated for the first time. This phenomenon can be employed for converting electromagnetic radiation into an electric signal. References 1; figures 2.

UDC 538.22

Reflection of Infrared Radiation by Bi-Sr-Ca-Cu-O Single Crystals and Their Magnetic Susceptibility

[Article by V.L. Arbuzov, O.M. Bakunin, A.E. Davlet-shin, S.M. Klotsman, V.L. Konstantinov, M.B. Kosmina, A.B. Levin, V.P. Semonozhenko, and I.M. Ysitsilkovskiy, Institute of Single Crystals, Kharkov, and Institute of Metal Physics, Stocktaking and Distribution Department, USSR Academy of Sciences, Sverdlovsk]

[Abstract] An experimental study was made involving single crystals of $Bi_2Sr_{3-x}Ca_xCu_2O_{8+y}$ high-T_c superconductor materials, the object being to correlate their optical properties such as the reflection coefficient for infrared radiation with their electrical resistivity and magnetic susceptibility in both normal and superconducting states. Specimens of these single crystals were produced, from solution of melt with CuO as solvent, by crystallization with the temperature of the melt dropping from 1000°C to 800°C at a rate of 5°C/h. Measurements were made on a fresh specimen as well as on two specimens annealed on $ZrO_2(Y_2O_3)$ substrates in air at 850°C for 60 min, and at 880°C for 3 h, respectively, and then cooled to room temperature not faster than 5°C/min, both specimens having been heated to their respective annealing temperature at a rate of 7°C/min. Their infrared reflection spectra covering the 100-700 cm⁻¹ range were measured at 300 K and 4.2 K temperatures in nonpolarized light in an AFS-01 Fourier spectrometer with a 1.9 cm⁻¹ resolution. The magnetic susceptibility was measured in an alternating magnetic field of 0.1 Oe intensity 77.7 kHz frequency, with both quadrature components of the voltage induced in the measuring coil by the magnetizing current having been compensated at 100 K temperature. The electrical resistance was measured by the current-voltage method with a direct current, silver contact tabs having been deposited on the surface of each specimen. The results reveal an optical anisotropy and also an anisotropy of the superconducting energy gap. Anisotropy of the latter is evident despite the indeterminacy of critical temperature T_c and thus $2\Delta/kT_c$ readings. Figures 4; references 10.

UDC 537.638

Phase Transition in Lamellar TiS_2 Crystals

[Article by G.V. Lashkarev, A.V. Brodovoy, M.V. Rad-chenko, I.P. Mintyanskiy, A.L. Mirets, and M.V. Tovarnitskiy, Institute of Problems in Materials Science, UkSSR Academy of Sciences, Kiev]

[Abstract] An experimental study of the structural phase transition in lamellar TiS_2 crystals was made which involved magnetic and thermoelectric measurements. Specimens of these crystals were produced by mixing more than the stoichiometric amount of TG-100 titanium sponge with extra-pure 16-5 sulfur inside a quartz ampule and heating the mixture in a furnace to 830-850°C, with precision temperature control for prevention of overheating. Synthesis of titanium sulfide was completed in 96 h, its specific heat being 80 J/mol.K and the heat of reaction being 400 kJ/mole. The ampule with its content was then cooled in the furnace to room temperature at a rate of 90-100°C/h at the site of crystal growth. This process yielded crystals of $Ti_{1.001}S_2$, 0.25 mm thick and 10 x 20 mm² large with a = 0.3406-0.3412 nm and c = 0.5693-0.5699 nm lattice periods. Their magnetic susceptibility at temperatures covering the 4.2-77 K range was measured by Faraday's relative method on a precision microbalance and automatic compensation. The temperature gradient along layers and the thermo-e.m.f., for calculation of the Seebeck coefficient α and its temperature dependence over the 6-100 K range, were determined on the basis of temperature measurements with a Cu/Au:Fe thermocouple, readings taken at liquid helium and liquid hydrogen temperatures were corrected for the absolute thermo-e.m.f. of the copper electrode so as to ensure better accuracy. The crystal lattice was found to be paramagnetic over the entire 4.2-77 K temperature, possibly reflecting both Pauli and van Vleck paramagnetisms. The excess Ti was found to be responsible for directionality of the magnetic susceptibility, while it obeys Curie's law, and to determine the electron concentration in these crystals. Supplementary electrical resistance measurements have yielded an almost linear decrease of electrical resistivity with decreasing temperature down to approximately 50 K and then a slower decrease to a residual level down to 4.2 K. This and the temperature dependence of the magnetic susceptibility and of the Seebeck coefficient, characterized by change of slope at or somewhat below the 50 K temperature, are indicators of a structural phase transition occurring within that narrow temperature range and distorting the crystal lattice. Figures 3; references 14.

Inversion of Magnetic Field and Vortex Chain in Anisotropic Superconductors

[Article by A.M. Grishin, A.Yu. Martynovich, and S.V. Yampolskiy, Donetsk Institute of Engineering Physics, UkSSR Academy of Sciences]

[Abstract] The distribution of Abrikosov vortices and their magnetic field structure in uniaxially anisotropic type-II superconductors are analyzed, their magnetic field having here, not only a longitudinal component which can oppose the resultant magnetic flux in a vortex,

but also transverse components not appearing in isotropic type-II superconductors. The magnetic field distribution in an anisotropic one, corresponding to the minimum Gibbs (thermodynamic) potential, is described by the Ginzburg potential and the anisotropy of superconductivity referring to the electronic subsystem which is described by the "effective mass" tensor. Varying the Ginzburg potential independently of the magnetic vector potential A, as well as of both modulus f and phase ψ of the order parameter, leads to the Ginzburg-Landau equation, which is then simplified by omitting del f and the $(\varepsilon/\lambda)^2$ terms (ε - coherence length, λ - London length). Solution of the London equation for a straight solitary vortex by the Fourier method yields an integral representing the magnetic field distribution. Complete integration for a vortex parallel to any principal axis of the "effective mass" tensor yields an expression for the magnetic field distribution which can be asymptotically expanded. An analysis of singularities in those expansions confirms that inversion of the magnetic field results in mutual attraction of vortices, the energy of pair interaction becoming negative, so that vortex chains are formed. The orientation of a vortex chain in an anisotropic superconductor in an external magnetic field is found by varying the Gibbs potential with respect to five parameters on which it depends: two translation vectors, the angle between them, the angle between axis of anisotropy and direction of vortex chain, and the angle defining orientation angle of a unit cell relative to the basis plane. This is done for a uniaxial crystal in a mixed state. Magnetization hysteresis resulting in a "tilt" effect evidently occurs when the angle between the magnetic field vector and the axis of anisotropy is small. Numerical calculations have been made using experimental data on uniaxial $YBa_2Cu_3O_x$ and Ba-Sr-Ca-Cu-O crystals, also data on the laminar $NbSe_2$ superconductor. The authors thank A.A. Abrikosov for helpful discussion. Figures 7; references 22.

UDC 535.372+621.378.35

Radiation Emission by Electron-Hole Droplets or Laser Effect in Si Crystals

[Article by A.A. Kipen, Institute of Physics, UkSSR Academy of Sciences, Kiev]

[Abstract] In his letter to the editor, the author interprets radiation emission attributed to electron-hole droplets in Si crystals in terms of the laser mechanism: selective amplification of light emission by excitons, principally by stimulated emission of radiation during inelastic exciton-exciton interaction with participation of phonons, in total internal-reflection modes within the natural optical cavity formed by the crystal faces. Considering that laser emission occurs first at the frequency which satisfies the condition $\delta(h\nu) \equiv \rho_c(h\nu) - g_c(h\nu) = 0$ (g_c, ρ_c intrinsic gain and overall optical loss factor averaged over the length of the effective Fabry-Perot resonator corresponding to a given total-internal-reflection mode) and that the radiation intensity $I_0(h\nu)$ increases fast with increasing energy $h\nu$ (ν - frequency, h - Planck constant) especially in weakly doped Si crystals, the system of three nonlinear equations of laser kinetics according to this model has been solved numerically. The results confirm that the fall time of stimulated radiation emission decreases fast as the pumping power is increased and reveals that the fall time is frequency dependent, being shorter at frequencies at which amplification is stronger. Evidently stimulated radiation emission influences the kinetics of radiation emission by electron-hole droplets very little during inelastic exciton-electron or exciton-hole interaction and hardly at all during exciton-phonon interaction, even when the respective interaction constants are known to be large, which corroborates the proposition that inelastic exciton-exciton interaction plays the dominant role in the inversion process in an excited Si crystal. Figures 2; references 8.

UDC 621.315.592

Intense Cooling of Electrons in Nonuniformly Doped Semiconductors

[Article by Yu.G. Gurevich, V.L. Zozulya, and V.B. Yurchenko, Kharkov Polytechnic Institute imeni V.I. Lenin]

[Abstract] The feasibility of intense cooling of charge carriers and particularly electrons in semiconductors is examined, such cooling being necessary for abatement of noise in semiconductor devices and especially in radiation receivers. The heat balance in the electronic subsystem in a semiconductor with a longitudinally varying electron concentration and attendant current flow is described by a first-order ordinary differential equation for the electron temperature. The balance of thermal and electrical energy during cooling of the electron gas in a thin layer of a nonuniformly doped semiconductor with a sharp n^+ - n junction is described by a second-order ordinary differential equation for the electron temperature. This equation is solved for boundary conditions of electron thermalization at the metal contact tabs at both ends of the semiconductor device and a Peltier effect at the junction in the center. In addition to the a priori known upper critical current density at which Joule-effect heating begins, there is found to exist a lower critical current density at which Thomson effect cooling begins and above which the effective cooling length increases in the lighter doped region while it decreases in the heavier doped region. Cooling is evidently most intense at some current density between these two critical ones. In the general case of an arbitrarily doped semiconductor that first equation of heat balance during

intense cooling cannot be solved analytically, owing to nonlinear effects. Therefore, it was solved numerically by the ranging method on a Standard System 1061 computer for the boundary conditions of an electron temperature at both contact ends equal to the ambient temperature one, the attendant Cauchy problem being solved by both Adams and Runge-Kutta methods. From the standpoint of "equivalent" noise temperature as criterion, optimum cooling will occur when the region of maximum electrical resistance is the region of maximum and the impurity concentration profile dips within the active semiconductor layer. Theoretically lowering the noise temperature to below half the absolute ambient one, at which the electron gas departs appreciably from equilibrium, leads to instabilities of the solution to the equation of energy balance. Figures 3; references 7.

UDC 537.311:539.2

X-Ray Photoelectron Spectra of $As_x(GeS_2)_{100-x}$ Films and Local Coordination of Atoms

[Article by Yu.Yu. Babinets, O.Yu. Gorkun, V.V. Milenin, V.M. Mitsa, B.A. Nesterenko, and A.A. Naumovets, Institute of Semiconductors, UkSSR Academy of Sciences, Kiev, and Uzhgorod University]

[Abstract] An experimental study of vitreous $As_x(GeS_2)_{100-x}$ films was made, for the purpose of determining the concentration profile of each element and the local coordination of atoms in them. Films with x = 3, 10, 40 atom.% As were produced by the method of discrete vaporization on SiO_2 substrates. The atomic content and the chemical composition of successive layers, prior to their being etched away with Ar^+ ions, was measured by x-ray photoelectron spectroscopy in an ES 2401 spectrometer with 1253.6 eV radiation from an MgK_α source. The profiles of As,Ge,S and also of Si,O reveal at least three regions with blurred boundaries. Within the approximate 5 nm thick subsurface layer all three As,Ge,S concentrations were found to increase with depth. Within the middle layer their concentrations were found to level off, the As concentration after increasing to a higher level and the Ge,S concentrations after decreasing to lower levels. Within the 20-30 nm thick film-substrate transition layer, all three concentrations were found to decrease linearly to levels lower than at the surface, while the Si concentration increased with depth to a maximum at the interface. The oxygen concentration was found to follow different patterns depending on the film composition. In films with x = 3 atom.

As it increased from about 50 percent max level at the surface to its maximum level, first remaining at this level and then decreasing to below 50 percent max within the middle layer, and again increased within the transition layer to a maximum at the interface. In films with x = 10 atom.% As it increased linearly from zero at the surface

to about 25 percent max within the subsurface layer, remained at this level within the middle layer, and increased further within the transition layer to a maximum at the interface. In films with 40 atom.% As it decreased from about 35 percent max at the surface to zero within the subsurface layer, remained zero throughout the middle layer, and increased within the transition layer to a maximum at the interface. Figures 2; tables 1; references 10.

UDC 537.22

Transient Photocurrents in Corona-Charged Polytetrafluoroethylene Electrets Exposed to Ultraviolet Light

[Article by S.N. Fedosov and A.Ye. Sergeyeva, Odessa Institute of Technology for Food Industry imeni M.V. Lomonosov]

[Abstract] An experimental study was made concerning transient photocurrents induced by ultraviolet light in polytetrafluoroethylene electret films after their electrization by corona discharge. On one side of 10 μm thick PTFE films, 10 nm thick aluminum electrodes were deposited by vacuum evaporation. The films were then charged negatively on the other side by corona discharge from a tungsten electrode at a 14 kV potential, with a control grid at a constant 2 kV negative potential placed between electrode tip and film surface. The electret potential during and after a 10 min charging period was measured by the Kelvin method. After several days of subsequent aging their potential had stabilized within 500-550 V. The charged surface of the electret films was then repetitively exposed for up to 105 s to ultraviolet light of a PRK-2 lamp through a metal mesh at ground potential and 4 mm above the surface. The photocurrent was boosted by a U5-6 amplifier and then measured with a KSP-4 recording potentiometer. The transient photocurrent was found to be unipolar and to peak within 25 s, the peak becoming lower during each successive exposure but recovering to its maximum initial level after the electret films had been held in darkness for over 3 h. The transient photocurrent then dropped smoothly to zero after the light had been turned off. A theoretical analysis, based on a model which describes photic generation of charge carriers and their subsequent drift in an open electret, yields expressions for the amplitude of the transient photocurrent, for the time in which it reaches its amplitude exposure, and for the time in which decays to zero after cessation of exposure. The model is adjusted to the experiment, which makes the carrier transit time shorter than the carrier trapping time in a thin film in a high-intensity electric field so that both recombination and carrier capture can be disregarded. On the basis of this model are calculated the charge carrier mobility μm $(8.9 \times 10^{-15} m^2 V.s)$ and the impurity center concentration

N ($1.5 \times 10^{12} cm^3$) in these electret films, assuming the charge carrier release time and transit time are 53 s and 24 s respectively. These results confirm that PTFE has a p-type photoconductivity. Figures 1; references 4.

Electrophysical Properties of ZnS Films Produced by Magnetron Sputtering

[Article by P.I. Antonenko, Sh.M. Abdarshitov, and P.Ye. Troyan, Tomsk Institute of Automated Control Systems and Radioelectronics]

[Abstract] An experimental study of thin electroluminescent light-emitting Zn:Mn films produced by magnetron sputtering was made, its purpose being a determination of their electrophysical properties. The target, a ZnS + 4 wt.% Mn compact 90 mm in diameter, was placed in a magnetron containing cylindrical permanent magnets and a 13.56 MHz microwave oscillator with an up to 500 W power capability. Films were deposited on a glass substrate in an argon atmosphere under a pressure of 0.1 - 0.2 Pa, with the temperature of the substrate varied from room temperature to 250°C, and then heat treated. For microstructural examination under a transmission electron microscope, 50 nm thick films produced with four different combinations of sputtering and heat treatment temperatures were deposited on a freshly cut slice of a rock salt crystal through a carbon interlayer preventing epitaxial growth of these films. Films produced with the substrate at 100°C were found to be either amorphous or polycrystalline with fine grains. Raising the temperature up to 250°C made the grains of the film material become larger and heat treatment at 450°C for 1 h in an argon yielded films with a preferred grain orientation. The optical transmission spectrum of the ZnS:Mn films revealed a 3.2 - 3.3 eV edge of fundamental absorption, independent of the substrate temperature during film deposition. For measurement of the electrophysical properties, Al-ZnS:Mn-Al capacitor structures were built on glass substrates with aluminum plates deposited on both sides of 150-300 nm thick dielectric films by evaporation of an aluminum target at rates of 1-3 nm/s under a vacuum of 1.3 mPa maximum. The dielectric permittivity of these ZnS:Mn films was determined from the current-voltage characteristics of such a capacitor. This characteristic was not symmetric with respect to polarity of the applied voltage, evidently owing to differences between the two ZnS:Mn-Al interfaces. Holding under a constant voltage was found to result in slow relaxation of the direct current. The dielectric constant ε = 5-6 and the refractive index n = 1.8 for 582 nm yellow light indicate that the contribution of slow polarizations to the total polarization of ZnS:Mn films is small but their effect on local field intensity risers caused by redistribution of charges and contributing to a higher electric strength of the material can be substantial. Decreasing the rate of rise of the applied sawtooth voltage from 10 V/s to 0.1 V/s was found to lower the breakdown voltage from 33 V to 27 V, but decreasing it further did not lower the breakdown voltage much further. Polarization relaxation must, therefore, proceed much faster than current relaxation and the latter is evidently be associated with electroforming of the films. This was confirmed by faster current relaxation after aging, which also lowered the saturation direct current and symmetrized the current-voltage characteristic. The films were subsequently tested as a.c. light emitters in In_2O_3 - SiO_x - ZnS:Mn - SiO_x - Al structures, the combined thickness of the two SiO_x layers deposited by vacuum evaporation being 300 nm and thus equal to the thickness of the transparent ZnS:Mn film deposited by the ion-reaction method. Application of a sinusoidal 2 kHz alternating voltage induced emission of yellow-orange light of up to 150 cd/m^2 intensity when that voltage had reached the 150 - 160 V level. The authors thank A.A. Miller for performing the electron-microscope examination. Figures 3; references 4.

Abnormal Electron Instability of Uniaxially Compressed Polymers

[Article by A. N. Lachinov, A. Yu. Zherebov, V. M. Kornilov, Physics Department of the Bashkir Science Center at the Urals Branch of the USSR Academy of Sciences]

[Abstract] Many recent studies report a spontaneous abnormal increase in conduction in originally-dielectric polymer films with a decrease in their thickness. This may point to the existence of a critical thickness area within which an insulator-to-metal phase transition is occurring for a yet unknown reason. The results of investigations of electrical properties of thin polymer films in the insulator-to-metal phase transition area stimulated by an abnormally low uniaxial compression are presented. Polyphenylphthalide, a polyaromatic compound which is a film-forming soluble polymer, within which spontaneous conduction is observed at a film thickness under 200 nm, was used as the sample. A high sensitivity of electric properties of thin films to pressure was discovered. At abnormally low pressures of under 200,000 Pa, a dielectric-to-metal phase transition was observed with a conduction jump by a factor of 11 at the transition point. This phenomenon is explained by the authors in the framework of Mott's phase transition model. References 8: 4 Russian, 4 Western; figures 2.

Nucleation on Clusters During Phase Transitions of First Kind in Liquid Solutions

[S.F. Rastopov and A.T. Sukhodolskiy, Institute of General Physics, USSR Academy of Sciences]

[Abstract] An experimental study of thermal cavitation during laser-induced phase transitions of the first kind in binary solutions was made revealing an ordering of effervescence under continuous laser radiation during transition from a one-component liquid to a binary solution. Cavitation was induced with radiation from a continuous-wave Ar-laser having a power of 1 W, this radiation being focused by a lens onto the diagonal face of a right angle prism, also serving as the flat bottom of a cylindrical cup with the liquid solution. The temperature rise in the solution was indicated by the intensity of a probing He-Ne laser beam upon its total internal reflection in that prism. A single turn-on of the laser was facilitated by a shutter, this was necessary for monitoring fluctuations in that instant at which the critical nucleus of vapor has formed, and for measuring the degrees of superheat reached at that instant. Tests were performed with aqueous solutions of ethanol, with rhodamine G dye added as thermal sensitizer in quantities raising the absorption coefficient to approximately 200 cm^{-1}. The dye did not significantly influence the effervescence ordering process, which was verified by control tests involving excitation of thermal cavitation in pure water-ethanol mixtures with a CO_2 laser. The experimental data are analyzed on the basis of cavitation nucleation in a binary mixture in both a volatile component and a stable one, assuming a low concentration of the volatile component. The new phenomenon of effervescence ordering is shown on the basis of a Poisson probability distribution, adequately explained by vapor nucleation on clusters forming within the laser-affected zone and grown to a mass larger than critical as a result of concentration fluctuations, their size distribution closely fits Smolukhovskiy's law. In the experiment, moreover, effervescence ordering was observed over the 5-95 percent range of ethanol concentration. The authors thank P.P. Pashinin for support and fruitful discussions. Figures 3; references 11.

Thermodynamic Method of Calculating Fractal Dimensionality of Surface

[Article by A.V. Neymark, Institute of Physical Chemistry, USSR Academy of Sciences]

[Abstract] A new method of calculating the fractal dimensionality d_{fs} of a surface is proposed which does not require any conceptual model, namely on the basis of an adsorption isotherm according to the Kiselev equation relating the surface area of an adsorbate film to the thermodynamic adsorption integral: $S(P) = (RT/\sigma v_m)$ [Integral of log (P_s/P) dN from N to N_{max}] (S - surface area, P - pressure, P_s - pressure of saturated vapor, σ - surface tension of liquid adsorbate, v_m - molar volume of liquid absorbate, T - temperature, R - gas constant, N_{max} - adsorption under pressure P $\rightarrow$ P_s). This relation of work balance implies that the absorbate surface has a uniform curvature, the average curvature of menisci being $r_k = 2\sigma v_m/RT\log (P_s/P)$ according to the Kelvin equation. The fractal dimensionality of an adsorbent surface is then $d_{fs} = 2 - [d[\log S(P)]/d[\log(r_k)(P)]]$, d_{fs} being defined by the relation S(r) proportional to r^{2-d} where S(r) is the area of the surface measured with a gage of dimension r. The fractal surface dimensionality of nitrogen-adsorbing activated carbon has been calculated by this method and also on the basis of the corresponding desorption isotherm, experimental data on the two isotherms having been processed by linear regression. The agreement is satisfactory, with $d_{fs} = 2.73$ approximately over the 1-20 nm scale range according to the adsorption isotherm and $d_{fs} = 2.71$ approximately over the 1-12.5 nm scale range according to the desorption isotherm, even though adsorption by real substances involves some hysteresis in mesoscopic pores and that the difference between corresponding adsorption and desorption isotherms becomes appreciable within the range of capillary condensation. The fractal dimensionality of a surface can also be calculated from readings of a mercury porosimeter, according to the Ruteyre-Prentzlau analog of the Kiselev equation for impregnation with an nonwetting liquid. The author thanks M.M. Dubinin for supplying tabulated experimental data and P.I. Ravikovich for assisting with calculations. Figures 1; references 12.

Superradiative Phase Transition in Semiconductors and Semimetals

[Article by V.A. Borisyuk, Institute of Physics imeni L.V. Kirenskiy, Siberian Department, USSR Academy of Sciences]

[Abstract] The possibility of a superradiative phase transition of the second to an ordered state is analyzed, for a homogeneous ordered phase, from the standpoint of stability of the normal phase at zero temperature. The spectrum of natural oscillations of the electromagnetic field, and thus of photons, is calculated with the aid of only one of the Maxwell equations, namely the one for curl H, and the "effective mass" model of electrons in a semiconductor or in a semimetal with allowed dipole transition between given bands. For solution of the

problem, its Hamiltonian $H_0(k)$ (k denoting the momentum or quasi-momentum of an electron) is formulated in terms of the velocity operator in Bloch functions and the energy of an electron with momentum k in the conduction band according to the Luttinger-Kohn method (PHYSICS REVIEW Vol 97, 1955, p 869). A term representing a uniform electric field, in which case the vector potential A does not vary in space, is then added to the Hamiltonian and the latter is thus generalized to $H(k) = H_0(k - eA/c)$ (e- charge of an electron, c- speed of light) following the gradient-invariant approach. The high-frequency oscillations are found to decay so that conditions for instability resulting in a phase transition of the second kind do not arise in a semiconductor, nor in a superradiative transition in a semimetal with an arbitrarily weak coupling. These conclusions have important implications concerning the electronic mechanism of ferroelectricity based on the theory of superradiative phase transition, the mechanism based on the theory of excitons in dielectrics appearing to be more plausible. The author thanks E.G. Batyiev, A.P. Kazantsev, A.I. Larkin, V.L. Pokrovskiy, V.I. Ponomarev. and M.V. Entin for helpful pertinent discussions, K.S. Aleksandrov, B.A. Volkov, B.I. Ivlev, Ye.V. Kuzmin, S.A. Moskalenko, K.N. Alekseyev, and A.F. Sadreyev for otherwise helpful discussions, A.K. Tsikh and A.P. Yushakov for interesting discussion of several relevant mathematical problems. Figures 2; references 37.

On the Possibility of Deuteron Superfluidity Associated With Hydrogen Dissolution in Metals

[Article by A. M. Kosevich, Engineering Physics Institute of Low Temperatures at the Ukrainian Academy of Sciences, Kharkov]

[Abstract] Some metals, especially palladium, are capable of dissolving large quantities of hydrogen and deuterium. If the deuterium density in the metal is such that there is one or more deuteron per cell, impurity particles may be able to move rather freely in the lattice. The topic discussed in this article was the possibility of a new type of deuteron superfluidity system in a metal which manifests itself when the number of deuterium atoms dissolved in the metal is commensurate with the number of host metal atoms. Assuming that a Bose-condensation of deuterons (bosons) occurs when their concentration is high, a transition of the d-system to a superfluid state is possible. Since deuterons are charged, such a superfluidity will be accompanied by certain superconductivity. The author thinks that today's physical experimentation technology will make it possible to resolve the issue of the existence of said peculiar properties of hydrogen in metals. References 1.

UDC 621.373.826.038.823

Emission Characteristics of Continuous-Wave CO-Laser With Longitudinal Electric-Discharge Excitation and Cryogenic Cooling

[Article by G.M. Grigoryan, B.M. Dymshits, and Yu.Z. Ionikh, Leningrad State University]

[Abstract] An experimental study of a continuous-wave CO-laser with longitudinal electric-discharge excitation and cryogenic cooling was made for the purpose of determining the influence of the operating conditions on its energy characteristics. The discharge tube, 23 mm in diameter, consisted of two connected parallel halves relative to the gas stream and across the voltage source, the gas mixture flowing from that tube into a vacuumized chamber after having been analyzed in a mass-spectrometer. The optical cavity was formed by a spherical gold mirror with an $r = 10$ m radius of curvature and a plane-parallel germanium plate with a $T = 0.5$ transmission coefficient. As active medium were used He-CO-N_2 - O_2 and He-CO-O_2 mixtures in various ratios, addition of nitrogen having been found to maintain a high efficiency over wider ranges of pressure and current. On the basis of power and flow rate, measurements have determined the dependence of both output power and efficiency with each mixture on the input power (up to 900 W), on the gas pressure (5 - 25 mm Hg), on the gas flow rate (0.1 - 13 dm^3/s), and on the length of the discharge gap (60 - 130 mm), the minimum current for glow discharge varying over the 20 - 80 mA range and the maximum current not exceeding 120 mA. Maximum power and efficiency of 850 W and over 45 percent respectively were at the top of pressure and input power ranges with a gas flow rate of only 0.4 - 1 dm^3/s. The emission spectrum of the laser with each active mixture was measured over a wide range of specific input energy (800 - 3500 J/g), gas flow rate (0.15 = 6 dm^3), and gas pressure (6 - 20 mm Hg), of interest being the short-wave edge determined by vibrational quantum number and its dependence on the specific input energy. Figures 5; references 15.

UDC 621.373.826.038.823

Regenerative Amplification of Narrow-Band Radiation in XeCl* Excimer Laser

[Article by M.S. Dzhidzhoyev. S.V. Dolgiy, I.A. Kudinov, V.T. Platonenko, Ye.V. Slobodchikov, and M.K. Shayakhmetova, Moscow State University imeni M.V. Lomonosov]

[Abstract] The feasibility of high-contrast regenerative amplification of narrow-band ultraviolet radiation in XeCl* excimer power lasers is examined on the basis of a numerical simulation and an experimental study. For the experiment, two kinds of optical cavity were tested: a ring cavity formed by plane mirrors and unstable telescopic ones. Selection of a ring cavity, not an optimum one in terms of maximum energy output, was based on its being very convenient to experiment with and being easy to describe for theoretical analysis. The analysis is based on numerical solution of the equation for the longitudinal intensity gradient of signal radiation, equal to the product of intensity and population of the initial state times the double sum over vibrational numbers and rotational numbers of cross-sections for B-X transitions at the radiation frequency with the vibrational numbers changing from v_B to v_B and the rotational numbers changing from $j + \Delta$. The population of the final state is assumed to be negligible. The signal is assumed to be a Gaussian one with variable amplitude, duration, and position in time. Experiments were performed with two amplifier cells: one 1 m long containing 12 x 28 x 600 mm^3 of the active medium inside a telescopic cavity (M = 7) for free-running emission in pulses of 0.5 J energy and 60 - 80 ns duration above at half amplitude, one 1.1 m long containing 24 x 40 x 700 mm^3 of the active medium inside the ring cavity or free-running emission in pulses of up to 3.5 J energy. The ring cavity was formed by three plane aluminum mirrors with reflection coefficient R = 0.75 approximately, and an 8 mm thick quartz plate with a 0.5° taper. The telescopic cavity was formed by a concave mirror and a convex one, each with an aluminum coating and a reflection coefficient R = 0.70 approximately, radiation from the oscillator entering through either a hole in the concave one or as a plane backward wave around the convex one. The hole was 1 - 4 mm in diameter and the magnification was M = 7 - 7.5 depending on the mirrors used. The master oscillator generated radiation with a 0.015 cm^{-1} wide spectral band tunable over an 80 cm^{-1} wide frequency range covering 0 - 0, 0 - 1, 0 - 2, 0 - 3 transitions in the B-X band, the radiation beam 3 x 10 mm in cross-section with a nearly diffractional divergence carrying 5 - 6 cavity modes 0.0027 cm^{-1} apart. The amplifier consisted of two lenses and a diaphragm, which formed a matching telescope, with a spatial filter for protection of the oscillator components. The amplifier and the oscillator were synchronized within 5 ns. All experiments were performed with neon mixtures. The energy of a 60 ns pulse reached 200 mJ at 0 - 1 and 0 - 2 transitions, 40 mJ at 0 - 0 and 0 - 3 transitions. The radiation energy was controlled by means of optoacoustic transducers and measured with a calorimeter for calculation of the contrast, and the pulse form was recorded with the aid of selectively switching 22-SPU photodetectors on S8-12 oscillographs. A spectrograph with 3 cm^{-1}/mm dispersion, consisting of a diffraction grating of 2400 lines/mm, a spherical mirror, and a diaphragm in the focal plane of the mirror, was capable of reliably extracting radiation beams generated at any of the four transitions. The results indicate the feasibility of regeneratively amplifying radiation of an XeCl* laser with a power contrast ratio up to 15 at the weak 0 - 0 and 0 - 3

transitions and with a power contrast ratio exceeding 10,000 at the strong 0 - 1 and 0 - 2 transitions. Figures 5; references 11.

UDC 621.373.826

Role of Multistage Collisions of Second Kind in Ionic Mercury Laser

907J0085C Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 17 No 6, Jun 90 pp 712-716

[Article by D.A. Korogodin, Ye.L. Latush, M.F. Sem, and G.D. Chebotarev, Rostov State University, Rostov-na-Donu]

[Abstract] The role of multistage exoergic in excitation of lasing levels in mercury ions is examined by comparative analysis of experimental data pertaining to the time characteristics of radiation emission at Hg-II transitions and a mathematical model describing the active medium of a He-Hg laser. The model contains equations of population balance at Hg-II levels below the $9^2S_{1/2}$ level, including radiative transitions between excited states and transitions induced by collisions with electrons. Populations are calculated with the Dyson charge transfer reaction $He^+ + Hg \rightarrow He + Hg^{*+*} + \Delta E$, the Penning multistage reaction $He(M) + Hg(M) \rightarrow He + Hg + e$, the collisional-radiative recombination $Hg^{++} + e + e \rightarrow Hg^{+*} + e$, and the multistage reaction $Hg(M) + Hg^+ \rightarrow He + Hg^{++} + e$ taken into account. The probabilities of optical and collisional transitions are calculated by the Sobelman-Vaynshtayn method, those of transitions to the ground state by the Bieberman-Holstein method with resorption taken into account. The model also contains a system of differential equations for the electron temperature and the concentration of long-lived heavy particles: Hg^+ ions, Hg^{++} ions, metastable Hg atoms (6^3P), metastable He atoms $(2^3S, 2^1S)$. The equation for the electron temperature accounts for heating of the electron gas during recombination, during de-excitation of metastable atoms, during ionizing collisions of metastable He atoms as well as during collisions of other metastable particles, and during Joule-effect. The model is made to approximately fit experimental data by stipulation of the values of measurable external parameters: length and radius of the discharge tube, partial pressures of the mixture components, voltage, amplitude and duration of a current pulse. The rates of inelastic collisions with electrons are calculated on the basis of experimental data including the cross-section for each process, assuming a Maxwell energy distribution of electrons. The results indicate that the principal mechanism of electric discharge pumping in the afterglow is collisional-radiative recombination with a small role played by the multistage $He(M) + Hg^+ \rightarrow He + Hg^{+*} + e$ reaction in emission of 567.7 nm radiation and the charge transfer reaction with a negligible role played by the Penning multistage reaction in emission of 615 nm radiation. Figures 4; references 31.

UDC 681-068

Nonlinear Fiber-Optic Reflector for Passive Mode Locking

907J0085E Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 17 No 6, Jun 90 pp 733-735

[Article by A.G. Bulushev, Ye.M. Dianov, and O.G. Okhotnikov, Institute of General Physics, USSR Academy of Sciences, Moscow]

[Abstract] An optical scheme of a laser with a nonlinear fiber-optic loop reflector is proposed for automatic passive mode locking by way of interferential pulse compression, this loop and a plane 100 percent reflectance mirror forming the optical cavity. The straight lead-in segment of the fiber is coaxial with the active element, from which radiation is picked up through a focusing lens. An asymmetric coupler terminates into both ends of the fiber loop which includes a nonreciprocal element located closer to one end than to the other. Radiation beams propagating through the loop in opposite directions are also out of phase, owing to their different power contents. This fiber loop is a linear reflector at low radiation intensity levels and becomes a nonlinear one with phase self-modulation as the radiation intensity is increased, the nonreciprocal element ensuring a phase difference between opposing radiation beams in the low-intensity linear case. When the nonreciprocal difference phase is not larger than 180° and is opposite to the nonlinear difference phase, then the reflection coefficient for high-power radiation is also high and conditions for positive feedback are realized. With the nonreciprocal element included, there are, in effect, two coupled optical cavities of different optical lengths through which radiation propagates in opposite directions. A nonreciprocal difference phase can be introduced by rotation of the loop, or as a consequence of the Faraday effect, or by asymmetric insertion of a phase modulator inside the fiber. For a performance analysis of such reflector, propagation of radiation through it is described by the nonlinear Schroedinger equation in a system of traveling coordinates. Figures 3; references 11.

UDC 535:621.373:826:539

Generation of Microwaves in Plasma of Optical Breakdown Induced by Modulated Laser Radiation

907J0085F Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 17 No 6, Jun 90 pp 741-743

[Article by A.A. Antipov, A.Z. Grasyuk, L.L. Losev, and V.I. Soskov, Institute of Physics imeni P.N. Lebedev, USSR Academy of Sciences]

[Abstract] An experimental study of laser action on an optical-breakdown plasma was made for verification of the authors' model which describes modulation of the electron temperature, and thus of the thermo-e.m.f. at

the detonation-absorption front owing to modulation of the laser radiation intensity. The model is based on the results of an experiment with a two-frequency laser and a plasma under atmospheric pressure, which has demonstrated the possibility of such a laser modulating the plasma electron temperature along with the thermo-e.m.f. at the difference frequency. Consequently, this generates microwaves of that frequency, infrared radiation within the 1 μm band having in this way been converted into ultrahigh-frequency radiation within the 0.6 GHz band and the latter into electric signals. A two-frequency laser for the verifying experiment was produced by means of stimulated Mandelshtam-Brillouin scattering in two different active media, the apparatus including a $YAG:Nd^3$ master oscillator, three amplifiers, and two Brillouin mirrors. The oscillator, operating in a single mode with Q-switching by a saturable dye, emitted radiation in pulses of the order of 20 ns duration. This radiation passed through a spatial filter, whereupon the beam passed successively through a Glan-Fresnel prism, two amplifiers, and a phase-shifter plate before being split into halves by a 45° 50 percent plane mirror. Each half beam was focused onto and then reflected by a Brillouin mirror, one in a cell filled with liquid acetone and one in a cell filled with methane under a pressure of 60 atm. The two reflected beams returned to the splitter plate and returned together through the phase-shifter plate, where their linear polarization was rotated through 90° relative to the polarization of the pumping radiation, and then through the two amplifiers to the Glan-Fresnel prism. This prism deflected them to a plane mirror for reflection to the third amplifier. This amplifier delivered radiation pulses of 150 mJ energy in a beam 6 mm in diameter, the beam divergence not exceeding 1 mrad. Use of acetone and methane as active media in the Brillouin mirrors made it possible to modulate the intensity of the laser radiation at a frequency of 2.2 GHz. A plasma was generated by focusing the laser radiation through a lens onto the base surface of a metal cylinder. The latter was connected through an isolation capacitance and a cable wire to a D603-diode detector for measurement of the thermo-e.m.f. signals from the metal plasma, particularly their microwave component. The modulation percentage of the plasma electron temperature and of the plasma thermo-e.m.f. was found to depend not only linearly on the energy of laser pulses and the intensity of laser radiation, but also on the absorption coefficient characterizing the optical properties of the plasma. Efficient conversion of the laser radiation into 10^6 - 10^8 MHz microwaves required connecting the thermo-e.m.f. source with a resistive-capacitive internal impedance to the load through a matching transformer, a quarter-wave strip line on a dielectric (teflon) film, and focusing the radiation on one of the transformer electrodes. Measurements revealed a linear dependence of the average microwave signal power on the energy and the power density of an incident laser pulse. The conversion efficiency in this experiment with a laser power of 5 MW reached 10^{-7}. Figures 6; references 7.

Current Generation and Plasma Front Propagation Induced by Action of Two Laser Pulses on Target in Air

[Article by E.M. Barkhudarov, G.V. Gelashvili, G.G. Gumberidze, and M.I. Taktakishvili, Institute of Physics, GSSR Academy of Sciences, Tbilisi]

[Abstract] A study was made concerning action of two successive laser pulses on a target in air, a CO_2 laser and a copper target were used in the experiment. The energy of each pulse was varied, that of the first one over the 1.5-12 J range and that of the second one over the 1.5-50 J range, both pulses being approximately 1.5 μs duration and the time lag between them being varied over the 1-100 μs range. The radiation was focused within a spot about 4 mm in diameter on the target, a disk 6 mm in diameter serving as one electrode and connected to a low-resistance noninductive electric load. The other electrode was a copper ring coaxially parallel to the disk and separated from it by a 1 mm long gap. The current generated by the second pulse was found to increase as the energy of either that pulse or the energy of the first one were increased, a low-energy first pulse of 1.5 - 5 J energy, maximally raising the current after the second one. The current was found to depend nonmonotonically on the time lag between pulses, peaking after a time delay within the 8 - 15 μs to a maximum depending on the pulse energy. The efficiency of this mode of energy conversion remains approximately the same throughout. The plasma front was found to travel at an almost constant velocity, beginning later but at the same speed after two equal low-energy pulses than after a single pulse of higher energy. The efficiency of this mode of energy conversion had remained approximately the same throughout. Shadowgrams of plasma kinetics under atmospheric pressure were obtained with the aid of an OGM-20 laser emitting 0.69 μm radiation in pulses of 25 ns duration, with the external ring electrode removed. They revealed an outgoing shock wave and a "fire ball" after two equal pulses of 3 J energy incident 10 μs apart, a second pulse of higher than 10 J energy causing breakdown at the periphery of the "fire ball" and a single pulse of higher than 5 J energy elongating the "fire ball" as well as elongating the shock wavefront in the direction of the laser beam. A pulse of sufficiently high energy caused a sharply discrete energy release and generated a smaller current, a second pulse then caused breakdown farther away, but no discrete energy release occurred when a second pulse of 40 - 50 J energy had been preceded by the first one of 1.5 - 5 J energy. Figures 4; references 4.

Tunable Single-Frequency XeCl* Excimer Laser

[Article by M.S. Dzhidzhoyev, S.V. Krayushkin, and V.T. Platonenko, Moscow State University imeni M.V. Lomonosov]

[Abstract] An experimental XeCl* excimer ultraviolet laser was built with a Fox-Smith reflecting intracavity selector for single-frequency emission with regenerative amplification of the narrow-band signal and for a maximally wide tuning range. The selector consisted of two fixed plane mirrors in quadrature positions behind the amplifier cell, one in a plane perpendicular to the axis of the amplifier cell and one in a plane parallel to it, with a beam-splitter plate at the intersection of the two mirror axes oriented at 45° to each. The amplifier cell, between two diaphragms, was placed behind the plane "open" exit mirror. For tuning, the selector was replaced by a diffraction grating with 2400 lines/mm while the selector acting now as a "closed" exit mirror replaced the "open" one. The diffraction grating was positioned behind a prismatic telescope with about 30x magnification for autocollimation of the second diffraction order and for normal reflection of the first diffraction order onto an opaque plane mirror parallel to it and formed with it an auxiliary interferometer. The spectra of emission pulses in each mode of operation were analyzed with a Fabry-Perot interferometer on a 70 mm base and their densitograms as well as the waveform and time parameters of emission pulses were recorded on an S7-15 high-speed oscillograph with the aid of a Fabry-Perot etalon. The distance between the two selector mirrors via the beam-splitter was varied, one transverse mode being extractable by means of two diaphragms with holes 1 mm in diameter but already two modes of nearly equal intensities and 0.07 cm^{-1} apart, appearing when that distance had been shortened to 4 cm (intrinsic cavity modes were 0.004 cm^{-1} apart). Tuning was done by rotation of the diffraction grating together with the interferometer mirror, an 85 cm^{-1} wide tuning range having become feasible. Emission pulses of approximately 5 µJ energy were attained at wavelengths within valleys of the tuning curve, this energy being still sufficient for regenerative amplification with high contrast. Figures 2; references 7.

Tunable Narrow-Band XeCl* Excimer Laser

[Article by I.A. Kudinov, V.T. Platonenko, and Ye.V. Slobodchikov, Moscow State University imeni M.V. Lomonosov]

[Abstract] A tunable XeCl* excimer laser with a dispersive optical cavity was tested for emission characteristics, the cavity being, in terms of generated modes, similar to a quasi-concentric one, with the exit mirror almost in the focal plane of the lens before the Fabry-Perot etalon on the back side of the active medium. That etalon, a 5 mm thick quartz plate, was followed by a diffraction grating with 2400 lines/mm positioned for autocollimation of the second diffraction order, and for normal reflection of the first diffraction order onto an opaque plane mirror parallel to it and forming with it an auxiliary interferometer. Radiation was extracted in the zeroth diffraction order with 27 percent reflectance or through a mirror, from either an opaque one (95 percent reflectance) or a semitransparent one (18 percent reflectance). In the latter case the laser beam reached the exit mirror after passage through two diaphragms, the first one having a circular hole and the second one having a narrow slit. Two diaphragms with a different circular hole each, one 0.5 mm in diameter and one 9 mm in diameter, were used for different experiments. Emission of narrow-band pulses of up to 200 µJ energy was attained in the presence of a wideband background noise with a high contrast relative to the latter, their spectrum narrowing during the pulse duration down to 0.015 cm^{-1} at the end of a pulse. They were tunable over an 80 cm^{-1} wide range, covering all the four 0 - 0, 0 - 1, 0 - 2, 0 - 3 transitions within the B-X band of a XeCl* molecule. The authors thank A.A. Karabutov, V.K. Popov, and M.A. Sagoyan for assistance, M.S. Dzhidzhoyev and S.V. Krayushkin for helpful discussions. Figures 4; references 7.

Comparative Evaluation of YalO$_3$:Nd^{3+} and YAG:Nd^{3+} as Active Media for Compact Periodically Pulsed Laser With Stimulated-Mandelshtam-Brillouin-Scattering Mirror

[Article by P.P. Pashinin, V.S. Sidorin, and Ye.I. Shklovskiy, Institute of General Physics, USSR Academy of Sciences, Moscow]

[Abstract] Two solid-state active media for compact pulsed lasers with an SMBS (stimulated Mandelshtam-Brillouin scattering) mirror and radiation self-injection are comparatively evaluated with respect to their energy characteristics, YOA:Nd^{3+} (yttrium orthoaluminate) and YAG:Nd^{3+} (yttrium-aluminum garnet), the optical system of such lasers having been designed to involve the entire cross-section of the active medium in emission of radiation pulses in a single mode at a repetition rate of 20 Hz. The optical system consists of a plane-parallel etalon plate, a LiF:F$_2^-$ shutter, the active medium, a biconvex lens with a focal length of $F_2 = 300$ mm and a concavo-plane lens with a focal length $F_3 = -105$ mm forming a telescope with an angular magnification M =

1/3, a concavo-plane diverging lens with a focal length of -25 mm, a biconvex converging lens with a focal length of 70 mm, and an SBMS cell with $GeCl_4$. The cavity is formed by a plane mirror and the concavo-plane telescope lens. The performance of such a cavity with a telescope is described by the path-of-rays matrix, a product of six square matrices representing the single-pass path of light through the successive stages of the optical system. The experiment was performed with three $YOA:Nd^{3+}$ and three $YAG:Nd^{3+}$ rods: one of each 4 mm in diameter and 65 mm long, one of each 6.3 mm in diameter and 65 mm long, one of each 6.3 mm in diameter and 100 mm long. They were mounted on elliptical monoblocks with either an INP5/60 flash lamp for pumping the 65 mm long rods, or with an INP5/90 flash lamp for pumping the 100 mm long rods. The discharge circuit consisted of a 50 μF or 100 μF capacitor across the secondary winding of the pulse transformer in the power supply, the leads contributing to the circuit inductance. The active media were optically pumped with pulses of energy up to 30 J, and either 290 μs duration with the 50 μF capacitor or 360 μs duration with the 100 μF capacitor, the pulse duration being read at the 35 percent level. These lasers were tested as amplifiers, with a polarization either parallel or perpendicular to polarization of the master laser beam. The dependence of the laser beam radius at each of the two cavity mirrors on the telescope offset $\delta = L - (F_2 + F_3)$ (L - distance between the principal planes of its lenses) at various fixed frequencies. The frequency dependence over the 0 - 30 Hz range of the optimum telescope offset and the light spot radius on the exit mirror, and the dependence of the weak-signal gain on the pump pulse energy over the 5 - 60 J range, all these data are based on both calculations and measurements, which indicate that a $YOA:Nd^{3+}$ laser performs better than a $YAG:Nd^{3+}$ laser. A stronger thermal lens is evidently induced in it, owing to better thermooptical properties of a YOA host crystal and a higher concentration of Nd^{3+} ions. This laser was tested as an amplifier with another such laser as master oscillator in a two-pass scheme and with a cell containing CCl_4 as second SMBS mirror. Emission of short pulses of 1.5 ns duration at the 35 percent level and energy up to 0.5 J, their peak power reaching 100 MW, were emitted by this amplifier with polarization decoupling. Its efficiency was twice as high as that of a similar $YAG:Nd^{3+}$ laser and it remained stable at higher pulse repetition rates. The authors thank R.V. Serov for helpful discussion and favorable comments. Figures 7; references 9.

Theory of Transient Ablation of Polymers by Ultrashort Laser Pulses

[Article by N.P. Furzikov, Scientific Research Center for Technological Lasers, USSR Academy of Sciences, Troitsk (Moscow Oblast)]

[Abstract] Destructive ablation of polymer materials by ultrashort laser pulses is described as a thermal degradation process under transient conditions characterized by instability of the interference pattern and fluctuation of the absorption energy. A theory of this process is proposed which relates both the threshold energy density and ablation depth to relaxation of electron excitation by conversion into heat. For ramp pulses of randomly polarized and weakly focused radiation, assuming that no diffusion of heat takes place within the duration of such a pulse, the threshold energy density according to this theory is $\Phi_0 = [\pi(grc^3)kt_p]^{1/4}/(2\alpha)^{1/2})$ approximately (ΔT - temperature rise necessary for thermal degradation to occur within duration t_p of a laser pulse, α - coefficient of linear heat absorption, c,k,ρ - specific heat, thermal conductivity, and density of polymer material). The theory recognizes a difference between action of a nanosecond laser pulse and that of an ultrashort picosecond or femtosecond laser pulse, the relaxation time t_e for electron excitation into heat being much shorter than the duration of a nanosecond pulse but much longer than the duration of an ultrashort pulse. In the latter case, therefore, the heating rate is determined by the relaxation rate and the temperature rise to the necessary threshold rise will have to be higher. The difference is also manifested in the ablation depth, the latter being $h(\Phi) = (B\lambda/\alpha)^{1/2}$ $\log(\Phi/\Phi_0)$ approximately for nanosecond pulses and $h(\Phi) = (B\lambda t_0/t_e)^{1/2}\log(\Phi/\Phi_0)$ approximately for ultrashort pulses (B - double amplitude of self-induced polymer surface lattice, inversely proportional to the square root of the refractive index, λ - wavelength of laser radiation). In this case, while the surface lattice forms within duration of a laser pulse t_p, the temperature reaches the level necessary for its formation within the much longer time t_e so that the surface lattice forms under transient conditions and its effective double amplitude becomes accordingly $B\lambda t_p/t_e$. The results of calculations based on this theory agree closely with experimental data on ablation of polymethamethyl acrylate by 300 fs pulses of 248 nm radiation and by 160 fs pulses of 308 nm radiation. This agreement also confirms earlier estimates of the electron relaxation time as being on the order of 10^{-11} s. Figures 3; references 11.

Monokinetization of Atom Beams by Laser-Induced Photodetachment of Electron

[Article by L.A. Rivlin, Moscow Institute of Radio Engineering, Electronics, and Automation]

[Abstract] Monokinetization of an atom beam by photodetachment of an electron beam is considered, with regard to the concentration of the distribution of atoms with respect to one of the velocity components by decreasing the dispersion of their distribution. A method of achieving this is described which combines laser

techniques with other laser techniques rather than use light pressure, laser action overcoming Maxwell's demon and an external electric field removing its trap door. A collisionless flux of negative ions and a beam of laser photons are assumed to propagate collinearly along the z-axis, the ions with random velocity and momentum distributions owing to the finiteness of their temperature and to the variability of their initial conditions which are accelerated by a constant external electric field. Photoneutralization of such an ion can occur, by virtue of the Doppler effect, only after its longitudinal velocity has reached or exceeds the threshold level at which the Doppler energy shift of laser photons becomes equal to or larger than the electron photodetachment energy. A remaining neutral atom continues to propagate at that velocity without further acceleration. The distribution of longitudinal velocities in the resulting beam of atoms is obtained from the frequency dependence of the ion flux and of the cross-section for photodetachment of electrons, considering that they are photodetached neither simultaneously from every ion nor instantaneously from any one. Incomplete monochromatization of the laser beam and sluggish photodetachment of electrons from negative ions are evidently the principal causes of a large dispersion of longitudinal velocity, which would be most readily confirmed by a real experiment involving negative Rb or Cs ions. Other than generating monokinetic high-energy and high-intensity atom beams, the method could also be used for increasing the coefficient of negative absorption by weakening the detrimental anisotropic influence of Doppler-effect line broadening. References 2.

General-Purpose Tunable Laser

[Article by Yu.I. Baranov and N.I. Sizov]

[Abstract] An experimental general-purpose CO_2 laser has been developed, built, and tested in the Atmospheric Spectroscopy Laboratory which features a high-Q optical cavity and a wide wavelength tuning range. Its active element is a glass gas-discharge tube, with a GaAs window covering its one end at the Brewster slant angle and with a Covar flange at the other end where a bellows coupled to the flange through a vacuum-tight sponge seal connects the tube to the mirror compartment. The mirror is a gold-coated spherical one with a 1600 mm focal length on a piezoceramic corrective mount. While the gas-discharge tube is rigidly mounted inside the frame consisting of four Invar rods, the mirror compartment is mounted on hinges allowing small rotation about both vertical and horizontal axes. The laser frequency is tuned by means of a 90° corner reflector, rotatable about its vertical axis, which consists of a plane mirror and a diffraction grating with 100 lines/mm. The grating operates in the first diffraction order, the zeroth order being diverted, and with the spherical mirror forms the optical

cavity. The active gas mixture is admitted into and exhausted from the discharge tube through two separate valves, fresh mixture being optically pumped by an ILGN-706 pulsed gas laser, whereupon its emission frequency and power are stabilized by the same automatic frequency control system for the LG-74 industrial gas laser. The new laser was tested with three carbon isotopes in the CO_2 gas: $^{12}C^{16}$, $^{13}C^{16}$, and $^{12}C^{18}$. It was tested in the single TEM_{00} emission mode, each emission line being identified by means of an MDR-23 monochromator. Its emission power at vibrational-rotational transitions in either of the two $00^0 1$ - $10^0 0$ or $00^0 1$ - $02^0 0$ bands reached 3-5 W and remained stable within $1.0 = 1.5$ percent over a 1 h period of continuous operation. The beam was about 6 mm in diameter with a divergence of about 10 μ rad. Figures 1; tables 1; references 2.

Impulse Generation of a CO_2 Laser With Controllable VO_2 Mirror

[Article by N.F. Bochorishvili, Yu.M. Gerbshteyn, O.B. Danilov, V.A. Klimov, N.Yu. Sentsov, I.A. Khakhayev, and F.A. Chudnovskiy]

[Abstract] Pulsed radiation emission by a CO_2 laser in an optical cavity with a multilayer plane mirror containing a VO_2 layer was attained, the mirror being controlled and the cavity thus tuned by heating the VO_2 layer with radiation pulses from a glass:Nd laser until a dielectric-to-metal phase in this layer had occurred. Heating the appropriate mirror segment produced the desired emission mode. With the VO_2 mirror oriented for normal incidence of 10.5 μm radiation from the CO_2 laser, along its path were placed first a germanium beam-splitter plate and then a germanium lens. With the glass:Nd laser oriented for oblique incidence of its radiation on the VO_2 mirror, along the path of this radiation were placed BS-5 glass beam-splitter plate and then a two-lens objective for heating control based on energy density measurement. Each beam-splitter plate diverted a part of the respective laser beam to a plane metal mirror for reflection into an infrared detector, the CO_2 laser radiation diverted to a cryogenic KRT detector cooled with liquid nitrogen and the glass:Nd-laser radiation attenuated by an absorber stack to an FD-256 photodiode as detector. Initially, with the VO_2 mirror at 50°C, the CO_2 laser did not emit radiation. Continuous emission without control started when that mirror was heated to 63°C and then ceased when that mirror was cooled to 52°C. Pulsed emission by the CO_2 laser was attained upon excitation of that mirror by the glass:Nd control laser in pulses at a repetition rate of 12.5 Hz, with the control laser operating either in the free-running mode or Q-switched. In the free-running mode it delivered excitation pulses of 160 mJ energy and 0.5 ms duration, the undelayed emission pulses then being of the same duration. In the Q-switched mode it delivered excitation pulses of 20 mJ

energy and 40 ns duration to a mirror spot 1 cm in diameter, the emission pulses with a 1 μs rise time being delayed 400 ns. Figures 2; references 3.

Possibility of Contracting Emission Pulses by Cooperative Effect in Semiconductor Lasers With External Cavity

[Article by V.A. Yurevich, Institute of Physics imeni B.I. Stepanov, BSSR Academy of Sciences, Mogilev]

[Abstract] The possibility of a semiconductor injection laser such as a GaAs laser emitting ultrashort pulses of picosecond or even subpicosecond duration is examined theoretically on the basis of a two-level model, which describes such a laser with an external optical cavity that includes interaction of the light field at resonance and the active medium. This interaction is determined by the resonance-type dependence of the refractive index on the concentration of free charge carriers as well as by the dynamics of their interband transitions. First solved is the system of three equations of dynamics which accordingly describe the buildup of slowly varying amplitudes of a coherently polarized field at a given frequency in the nonlinear medium of an injection laser with coherent inversion and with an external cavity. It is solved analytically for both the time dependence and the spectrum of the radiation intensity in ultrashort pulses. It is then solved numerically for values of parameters covering the range typical of real GaAs lasers with appropriate pumping. As a consequence of switching hysteresis, characteristic of a nonlinear laser cavity, self-excited oscillations are generated which contain nondecaying subnanosecond intensity spikes whose period and contrast depend on the cavity parameters and on the pumping current. As the reflection coefficient of the external mirror decreases approaching that of the GaAs-diode face, the radiation losses in the cavity between the two being determined by the interference-wave reflection coefficient in it, the pumping power necessary for emission becomes higher and shorter pulses are emitted at lower repetition rates. Figures 1; references 13.

Initial Stages of GaAs Surface Fusion Under Femtosecond Laser Pulses: A Study by the Second Harmonic Generation Method

[Article by S. V. Govorkov, I. L. Shumay, W. Rudolf, T. Schreder, Moscow State University imeni M. V. Lomonosov and F. Schiller University, Jena, East Germany]

[Abstract] The results of a study are presented on the initial fusion phase on the GaAs surface under the effect of 100 fs laser pulses by the second harmonic generation and linear reflection methods. In contrast to linear reflection, the SHG efficacy depends on the crystal lattice symmetry in the near-surface layer which, according to the selection rules, should decrease in GaAs with a loss of the long-range order. It was discovered that the second harmonic intensity decreases with a characteristic time of about 100 fs while linear reflectance rises to a value characteristic of molten GaAs, much slower, with a time constant of 1 ps. The results make it possible to speculate that the crystal lattice's long-range order is lost while the lattice is still relatively cold, i.e., much faster than the change in the optical properties of GaAs which reflect the state of the close-range order. A laser system emitting spectrally-bound pulses with a half-amplitude energy of 0.1 mJ at a 620 nm wavelength was used in the experiments. The difference was measured between the second harmonic intensity and that of a linearly reflected test beam both with and without an exciting beam. The time constants were measured by approximating the experimental curves. Western references 8; figures 3.

Model for Describing Emission of Short-Lived Amplifying Media

[Article by M. Ya. Amusya, M. L. Shmatov]

[Abstract] A simple model is offered for describing stimulated emission of lasers without mirrors which takes into account the dynamic evolution of the medium parameters. The model is necessary, in particular, for describing the emission by inverting populations under the effect of powerful lasers on various targets. A unidimensional amplification model without saturation is examined. For clarity, the medium is assumed to be cylindrical and to have a detector on its axis. The dependence of the laser gain on time is being analyzed. Although the above model for measuring variations in the system parameters with time is not totally consistent with the results of numerical simulation, it is recommended for determining adjustment parameters on the basis of experimental data. The model fails to explain the decrease in radiation with an increase in the medium length; possible reasons for this phenomenon are to be studied in the future. Western references 11; figures 1.

UDC 539.124

Annihilation of Superradiation in Systems of Positronium Atoms

[Article by R.A. Vlasov, O.N. Gadomskiy, and M.G. Shageyev, Yelabuga State Pedagogical Institute, Tatar ASSR, and Institute Of Physics, BSSR Academy of Sciences, Minsk]

[Abstract] The possibility of annihilation superradiation in a homogeneous medium of parapositronium atoms during two-photon annihilation and attendant propagation of one γ-photon mode in a certain direction is considered, this being a far-gamma analog of Dicke optical superradiation. Passage of gamma annihilation radiation is analyzed on the basis of a simultaneous system of equations of motion in atomic and field variables, the Hamiltonian of the system of p-Ps atoms which interact with the field of annihilation radiation containing the sum of n products of p-Ps production and p-Ps annihilation operators. Replacement of summation with integration, in the case of a continuous medium, yields an integrodifferential equation which relates atomic variables to field variables. This equation is solved for the operator of generation of an annihilation γ-photon pair. From the solution to this equation, the time at which superradiation will reach its maximum intensity can be determined, this time being inversely proportional to the intensity of annihilation decay of an isolated parapositronium atom. It should be possible to detect annihilation superradiation, in view of the progress made in production of positrons, estimates indicating that its total power can reach 4 GW and that the time for it to reach maximum intensity is approximately 10^6 times shorter than the lifetime of free positronium atoms when their concentration is very low. Article was presented by Academician N.A. Borisevich on 5 February 1988. Figures 1; references 6.

Estimating Constituent Mass of Light Quark by Rules-of-Sums Method

[Article by A.A. Pivovarov, Institute of Nuclear Research, USSR Academy of Sciences]

[Abstract] The constituent mass of a light quark is treated as the mass parameter of a free fermionic propagator, which interpolates a two-quark locally gauge-invariant special Green function within a certain range of its argument. Estimation by operator expansion of this function over small distances, and comparison of this expansion with a free fermion propagator, yields a constituent mass m = 300+/-50 MeV. This mass, determined principally by the numerical values of quark condensate and quark-gluon condensate of dimensionality 5, is

obtained by applying the rules of sums in the configuration space. In the process of mathematical analysis and calculations, the constituent mass of a light quark as a principal parameter in potential models is shown to depend on fundamental parameters of quantum chromodynamics. The author thanks K.G. Chetyrkin for interest and helpful comments. References 6.

Threshold Effect in Processes Involving Emission of Lepton Pairs From Quark-Gluon Plasma

[Article by M.I. Gorenshteyn and O.A. Mogilevskiy, Institute of Theoretical Physics, UkSSR Academy of Sciences]

[Abstract] Emission of lepton pairs from quark-gluon plasmas during relativistic nuclear collision is analyzed in connection with CERN's experimental studies of quark matter. Taken into consideration for these studies are two ranges of invariant lepton pair mass which are known to exist within which a quark-gluon plasma can be expected to emit heat along with hadrons during attendant rigid processes of the Drell-Jahn kind: M = 1.5 - 2.5 GeV between ρ and J/psi resonance peaks and M < $2m_\pi$ below the threshold of $\pi^+\pi^-$ annihilation. This threshold and the spectrum of dileptons are calculated on the basis of the model of quark-gluon plasma evolution which involves integration over d^4x and includes nonperturbative effects but no low-momentum components of color charges. This model had been proposed for describing the behavior of thermodynamic functions at temperatures above the deconfinement point according to lattice SU(2) gas dynamics. The threshold momentum at the spectrum truncation edge is estimated by referring to lattice quantum chromodynamics and calculations by the Monte Carlo method, the latter having yielded values of the energy density above at deconfinement point which nearly or exactly fit the Stefan-Boltzmann law for the corresponding ideal gas. The dilepton spectrum calculated for mass M = 100 MeV and temperature T = 250 MeV indicates a particularly strong threshold effect when the mass is small. The authors thank V.A. Averchenkov, D.V. Anchishkin, K.A. Bugayev, V.M. Yemelyanov. and Ya. Pishuta for helpful discussions. Figures 1; references 14.

Strong Selectivity and Dependence of Maximum Ion Energy on Charge Number During Acceleration of Ions in Electron Beams

[Article by A.A. Kansuzyan, A.A. Plyutto. I.S. Korotkov, and G.R. Dzhobova]

[Abstract] An experimental study concerning acceleration of ions by electron beams in plasma diodes has

revealed a preferential acceleration of ions with higher charge numbers. The maximum energy is acquired by ions with the highest charge number, unlike acceleration of ions, independent of their valence number, by electron beams formed in vacuum-spark or vacuum-arc discharge plasmas. The experiment was performed with a pulsed vacuum-arc generator of aluminum plasma with an annular anode inside an alundum cylinder. The opposite wall was an annular 800 kV accelerating electrode, its inside hole allowing extraction of ions. The electron-beam forming, and ion-beam accelerating, drift space with residual gas between the two electrodes was shaped into a channel by a sequence of alternating insulator rings and metal diaphragms, the latter made of stainless steel with various bore diameters ranging from 3 to 10 mm. The amplitude of the arc current in the plasma generator was varied over the 40 - 100 A range, the current pulse duration remaining approximately 100 μs throughout. Outside the cylindrical chamber, behind the hole in the 800 kV accelerating electrode, a 20 kV decelerating electrode was placed for electrostatic extraction of ions. The composition of the extracted ion beam was analyzed in a Thomson mass-spectrometer with a K = 1730 instrument constant. The energy of ions was calculated as W = KZV/Y (Z - charge number of ion, V - deflecting voltage, Y - deflection of ion) with a correction for the different numbers of different ions, which had been determined on the basis of photometrical comparison of the blackening levels of nuclear emulsions. Analysis of the spectrograms indicates that the maximum-energy region along the Al_2 line has been formed as a result of $Al^{3+} \rightarrow Al^{2+}$ transition, while the high-energy region along the Al^{1+} line has been formed as a result of $Al^{3+} \rightarrow Al^{2+} \rightarrow Al^{1+}$ and $Al^{2+} \rightarrow Al^{1+}$ transitions. The data on ions which have retained their charge number confirm that their maximum energy depends on their charge number, $W(Al^{3+}):W(Al^{2+}) = 1.5^{2.7}$ when the arc current was 40 A and $1.5^{1.6}$ when the arc current was 70 A. The energy of accelerated Al^{1+} ions was not measurable, owing to the faintness of their lines. Evidently change of charge within the drift space containing residual gas is responsible for the dependence of the maximum ion energy on the ion charge number when ions are accelerated by an electron beam. Figures 2; tables 1; references 6.

Total Cross-Section for Radiative Electron-Ion Recombination

[Article by A.I. Milshteyn, Institute of Nuclear Physics, Siberian Department, USSR Academy of Sciences]

[Abstract] The total cross-section for radiative recombination of a nonrelativistic electron with a hydrogen-like ion and the total effective radiation emission during the recombination process are calculated in the dipole approximation. The calculations are based on the standard definition and the analytic properties of Green's function for an electron in a field of Coulomb forces $G^+(x,x'\varepsilon)$ and $G^-(x,x'\varepsilon)$ respectively in the upper half-plane and in the lower half-plane of the complex variable ε, with a discontinuity from 0 to ∞ corresponding to the continuous spectrum and with poles in the $\varepsilon < 0$ half-plane corresponding to the discrete spectrum. Derived from that standard definition are an integral equation for the wave function of an incident electron in the continuous spectrum with a jump of Green's function at the discontinuity, and an integral equation for the wave function of a final electron in the discrete spectrum, integration with respect to velocity of an incident electron in the continuous spectrum performed along the direction of its velocity, and integration with respect to energy ε of a final electron in the discrete spectrum performed along a contour which embraces all poles. The dependence of both the total cross-section for radiative recombination and the effective radiation flux on the parameter $\eta = Ze^2/hv$ (e - charge of an electron, $Z\varepsilon$ - charge of an ion, v - velocity of incident electron, h - Planck constant) is evaluated by this exact method, numerical results then being compared with those obtained by known asymptotic and interpolation methods. Figures 3; references 10.

Superradiance in System of Proton Spins

[Article by N.A. Bazhanov, D.S. Bulyanitsa, A.I. Zaytsev, A.I. Kovalev, V.A. Malyshev, and Ye.D. Trifonov, State Institute of Optics imeni S.I. Vavilov]

[Abstract] An experiment revealing superradiance in a system of proton spins was performed with a radio-frequency tank circuit resonating at a frequency of 54 MHz in a static magnetic field $H_0 = H_z$ normal to the axis (y-axis) of the inductance coil and a specimen of propanediol containing 4.5×10^{22} cm^{-3} proton spins inside the coil. Population inversion of Zeeman levels was achieved in an external magnetic field $H_0 = 2.45$ T, corresponding to a proton resonance frequency of 104.3 MHz, by dynamic polarization of nuclei with the aid of a paramagnetic impurity: 1.8×10^{20} cm^{-3} Cr^{3+} ions. The system of proton spins in that magnetic field, uniform within 10^{-2}%, was frozen by holding the temperature within 60 - 80 mK. The magnetic field was then scanned at rates up to 50 Oe/s, a strong radio-frequency radiation pulse or a series of them during slow scanning, with an attendant decrease or even reversal of magnetization being detected as the proton resonance frequency approached the 54 MHz resonance frequency of the tank circuit. Measurements revealed several laws characterizing this radiation phenomenon, namely, not only the polarization P_f after emission of a radiation pulse, but also the pulse amplitude and duration, depend on the initial polarization P_i above the emission threshold level (P - fraction of protons oriented along the external magnetic field). The experimental data are interpreted from the standpoint of superradiance theory and

described by a closed system of four equations: three Bloch equations of kinetics for the magnetic moment of a spin system in the resultant magnetic field $H = (H_x, 0, H_0)$, namely for the rates of change of magnetization components M_x, M_y, M_z and one equation for d^2M_x/dt^2 the circuit equation and Ampere's law for H_x. A close between theory and experiment is found to be attainable only by assuming an initial frequency deviation from resonance in the tank circuit $\Delta = 1.2\omega/2Q$ approximately and a relaxation time of 50 μs. The authors thank V.G. Davydov for assistance in numerical computations. Figures 6; references 12.

Sound Pulses Within Light Beam in Weakly Absorbing Medium. Paraxial Buildup of Sound and Refraction of Light

[Article by G.A. Askaryan, A.G. Krasnovskiy, and A.V. Yurkin, Institute of General Physics, USSR Academy of Sciences]

[Abstract] The behavior of sound pulses within a continuous light beam as they reach its axis is studied on the basis of theoretical relations and experimental data. As a model for the theoretical analysis, a light beam is selected which has a radial intensity distribution $I(r,t) = I_0(t)f(r)$ appearing in a pulse of duration τ much shorter than $t_s = a/c_s$ (a - median radius of light beam, c_s - speed of sound) and releases into the ambient medium, a weakly absorbing one, an energy $q(r)$ per cm^3 which raises the pressure in the medium by a pulse of increment equal to that energy multiplied by the Grüneisen constant $\Gamma = \beta c_s^2/C$ (β, C - coefficient of thermal expansion and specific heat of the medium). The equation of acoustics for perturbation of the radial pressure profile $p(r,t)$ is solved with the aid of Hankel transformation, the problem treated as an axisymmetric one. Analysis of the solution reveals a buildup of sound pressure around the axis of the light beam by superposition of a rarefaction wave converging toward the light beam axis on one diverging from it upon reflection, followed by refraction of the light beam in a subsequent pulse according to the time-dependent radial profile of the optical refractive index $n(r,t)$. The radial profiles of pressure perturbations $p(r,t)/p(r,0)-1$ and density perturbations $\rho c_c^2/p(r,0)$ at various instants of time covering a period from before to after the end of a sound pulse have been calculated for a sound pulse in a Gaussian light beam and in a hypergaussian light beam, also inside a tubular one with an annular radial heat release profile. An experiment was performed with a 10 cm long cell containing a liquid medium, ethyl alcohol or water, and a Nd-laser emitting light monopulses of 40-50 ns duration. Prior to entering the cell, the radial intensity profile of the laser beam was smoothed by removal of small-scale nonuniformities and

then transformed into one with a steep edge by passage through a 14 mm circular hole in a diaphragm. The latter could be moved along the optical axis over a 0 - 10 cm distance from the front face of the cell with liquid so that the sharpness of the light intensity distribution in the liquid could be varied accordingly, and with it the way quasi-cylindrical converging and diverging sound waves were formed. Acoustic measurements were made with two piezoceramic transducers. One of them was a microtransducer with a 15 MHz resonance frequency and a 0.005 W/atm sensitivity of the thickness mode. The other one was a tubular transducer with a 2 μs excitation pulse period and 0.5 W/atm sensitivity. Sound waves were also detected and measured by the method of optical refraction, namely by probing the paraxial region of the main laser beam with the beam of an He-Ne auxiliary laser. Figures 5; references 13.

Nonlinear Dynamics and Solitons in Spin Glasses

[Article by Yu.A. Beletskiy, B.A. Ivanov, and A.L. Sukstanskiy, Institute of Theoretical Physics, USSR Academy of Sciences]

[Abstract] Dynamics and stability of solitons in a completely amorphous spin system, such as spin glass, are analyzed, such a material representing simplest disordered media. The angle through which spins rotate from their equilibrium orientation is selected as the macroscopic physical variable, a function of the radius-vector and time $\theta(r,t)$. Both location and orientation of spins are completely random, the approximately pure exchange interaction of spins is determined by the SO(3)-group geometry. This group is parametrized through a unit four-dimensional vector nonlinearly related to $\tan(\theta/2)$, which produces a chiral model with a quadratic Lagrangian of its components. More components are added to account for relativistic interactions, the system then not retaining the momentum integral but retaining the wave integral N equal to the number of magnons along with the angular momentum M. That leads to the possibility of the existence of dynamic two-parameter solitons, those two parameters being their velocity v and precession frequency ω. The structure of dynamic bound (v = 0) solitons in spin glass is analyzed on the basis of the transcendental equation for the spin rotation angle θ. One of the projections of N is then used for quasi-classical quantization of solitons in spin glass, whereupon the soliton solution to that equation, appropriately including the anisotropy energy in spin glass, is analyzed for stability. The general theory is extended to and numerically evaluated for one-dimensional solitons and to centrisymmetric three-dimensional ones. Figures 3; references 13.

Relativistic Coulomb Quasi-Potential and New Narrow Resonances in Systems of Charged Particles

[Article by B.A. Arbuzov, E.E. Boos, V.I. Savrin, and S.A. Shichanin, Scientific Research Institute of Nuclear Physics at Moscow State University]

[Abstract] Evidence of positron-electron resonances in collisions between nuclei with high charges, such as Th + u or Th + Th, is examined. An explanation is sought by analysis of relativistic bound states in terms of the Coulomb quasi-potential in accordance with quantum electrodynamics and field theory. Following the Logunov-Tavkhelidze approach (NUOVO CIMENTO Vol 29 No 2, 1963), the quasi-potential in the staircase approximation is derived from the Bethe-Solpeter equation for the complete four-point Green function and then in explicit form demonstrated on the Wick-Cutsosky scalar fields interaction model (PHYSICS REVIEW Vol 96 No 4, 1954). The quasi-potential becomes the non-relativistic Coulomb potential and the Logunov-Tavkhelidze equation becomes the nonrelativistic Schrödinger equation at the nonrelativistic limit p,p' $<<$ m and M-2m $<<$ m, that equation and the quasi-potential having been projected onto frequency states but now being projected onto particle-antiparticle states. The integral equations obtained for the quasi-potential, $\varphi(p)$ being replaced with $\varphi(p')$ for S-states, is by substitution and normalization reduced to a one-dimensional integral equation. The latter is solved numerically and yields the dependence of $\alpha = e^2/4\pi$ and $-\alpha$ on E/m over the E/m = 0.7 - 1.6 range (E - energy level dependent on α, e - charge of electron, m - mass of bound state). The results agree very closely with the experimental data on occurrence of narrow resonances, sharp peaks of successively decreasing magnitude separated by steep dips. The authors thank A.A. Logunov and L.D. Solovyev for fruitful discussions. Figures 5; tables 3; references 30.

Soliton Dynamics in Constant Magnetic Field

[Article by L.S. Brizhik, Institute of Theoretical Physics, USSR Academy of Sciences]

[Abstract] Motion of a quasi-particle, electron or hole, in a highly anisotropic crystal is described by an equation which includes the interaction Hamiltonian, only interaction within atomic chains is considered here. The solution to the system of this equation and the strain wave equation is shown to be a wave function representing the product of plane transverse waves and a soliton which propagates along an atomic chain at a subsonic velocity. Evolution and dynamics of such a free soliton in a constant magnetic field are then analyzed, assuming a three-dimensional crystal with parallel atomic chains. In a longitudinal magnetic field, a quasi-particle is found to move as a soliton in a helix along an atomic chain and around closed orbitals in a transverse plane, with an energy depending on interaction of its spin ½ and the magnetic field. For motion of a quasi-particle in a transverse magnetic field, the strain wave equation is reduced to a nonlinear Schrödinger equation and the latter is solved, in the adiabatic approximation, by the perturbation method for inverse problems. The solution in this case is a function with an envelope of the same form as that of a soliton in the absence of a magnetic field, but moving at a velocity which oscillates in time, the cyclotron frequency of these velocity oscillations being determined by an effective mass of the quasi-particle, larger than the cyclotron mass of a free quasi-particle by a factor $1 + \delta$ (mass of soliton in magnetic field larger than mass of free quasi-particle by factor δ). The author thanks A.S. Davydov, A.A. Yeremko, V.N. Yermakov, and V.M. Loktev for helpful discussions. References 8.

Production of Superheavy Hydrogen Isotopes During Absorption of π^- Mesons by ^{6,7}Li Nuclei

[Article by A.I. Amelin, M.G. Gornov, Yu.B. Gurov, A.I. Ilin, V.P. Koptev, P.V. Morokhov, K.O. Oganesyan, V.A. Pechkurov, V.I. Savelyev, F.M. Sergeyev, B.A. Chernyshev, R.R. Shafigullin, and A.V. Shishkov, Moscow Institute of Engineering Physics, Joint Institute of Nuclear Research, and Institute of Nuclear Physics imeni B.P. Konstantinov at USSR Academy of Sciences]

[Abstract] An experimental study of the (π^- meson, ^{6,7}Li) reaction was made in search of superheavy hydrogen isotopes in two-particle channels of this reaction. A multilayer semiconductor-diode spectrometer was used for measuring the absorption of π^- mesons by ^{6,7}Li nuclei in the P2-channel of the synchrocyclotron at the Leningrad Institute of Nuclear Physics. Inclusive measurements were made covering the high-momentum component of the three p,d,t spectra and correlation measurements were made pertaining to coincidence of charged particles. The spectrometer recorded all products of reactions involving tritium, deuterium, and protium with a 1 MeV energy resolution up to the respective kinematic limit in the total-absorption mode, its error not exceeding 250 kev in tritium measurement and 500 keV in deuterium or protium measurement. With the residual system weakly excited, the readings of all energy distributions, except in the spectrum of protons on ^{7}Li, were higher than theoretical estimates taking into account the distribution of background energy. This discrepancy is adequately interpreted on the basis of the Breit-Wigner relation with an energy-dependent width of the resonance state line and indicates existence of the ^{4}H isotope. Indication of possible ^{5}H isotope production is

less distinct, owing to wide singularities in the proton spectrum, and there is no evidence of ^{6}H isotope production. The authors thank Professor A.M. Gorbatov for helpful discussions. Figures 3; references 10.

New Adiabatic Invariants in Problem of Two Hydrogen Atoms Far Apart

[Article by A.A. Belov and Yu.Ye. Lozovik, Institute of Spectroscopy, USSR Academy of Sciences]

[Abstract] A system of two Rydberg hydrogen atoms is considered in the adiabatic approximation, assuming that the distance between them is "frozen" and much larger than the radii of their Coulomb electron orbits. Owing to multiple degeneracy of the Coulomb spectrum, the motion of their electrons is strongly correlated even when the distance between their nuclei is large. Two problems are considered here, one of them concerning the asymptotic behavior of terms of a hydrogen molecule H_2 as the distance between its two atoms (their nuclei) tends to infinity. The other problem is that of two Coulomb impurity centers. The effective Hamiltonian of this system is obtained by averaging over fast varying phases and formulated in terms of Runge-Lenz vectors a,A subject to the commutative law of algebra for the direct sum $so(4) + so(4)$ that makes $1.a = L.A = 0$, $1^2 + a^2 = n^2$, $L^2 + A^2 = N^2$. These three relations pin the Casimir functions, which then yield the $Q(n,N)$ orbits of the $SO(4) \times SO(4)$ dynamic symmetry group $S_{n/2}^2 \times S_{n/2}^2 \times S_{N/2}^2 \times S_{N/2}^2$ with the intrinsic structure of a Kirillov-Costant-Souriot simplectic manifold. Only four involution integrals are needed, by virtue of Liouville's theorem, to prove that this dynamic system is exactly integrable and the Lax method is used to prove it. The condition for quantization is formulated as the requirement that the characteristic class of quantum separation be positive, according to N. Hart, and then applied to the specific case of electron orbits strongly elongated about the axis joining the two hydrogen nuclei. References 8.

Method of Determining Half-Life

[Article by V.Ye. Makarenko and G.A. Otroshchenko, Institute of Atomic Energy imeni I.V. Kurchatov]

[Abstract] A method of determining the half-life period $T_{1/2}$ in an ensemble of decay events spread over a period of time is described which applies even to situations where no events have been recorded in some channels and thus a logarithm of the number of events cannot be taken. The method is outlined for M time channels of equal intervals τ_0 in an experimental time spectrum and a total number of radioactive decay events N within one such time spectrum consisting of k channels, the compound event in each consisting of m elementary ones. The method involves calculating the probabilities of events after a recorded one and applying the maximum-likelihood principle. With the average number of events in the k-th time channel $n_k = A^{(-ak)}$ ($a = \tau_0 \log 2/T_{1/2}$) of a time spectrum beginning with channel n_1 and ending with channel n_2, the total number of events is $N = Aq(1 - q^M)/(1 - q)$ ($q = e^{(-a)}$). The half-life is then calculated by explicating q from the condition for maximum probability of a later compound event in the next channel. The relative error of this calculation can be estimated on the basis of given q and m. The probability of recording events within an entire time spectrum depends on the sum of all channels and not on any individual one, the probability of any ensemble of events with a given centroid being therefore determined by that given centroid. The method applies also to a negative half-life, in the case of an exponentially increasing q. The method is finally demonstrated on processing of experimental data (YADERNAYA FIZIKA Vol 50 p 928, 1989) on ternary fission of fissionable uranium isomers activated by neutrons, a pulsed electrostatic accelerator serving as the source of neutron beams and fission readings having been taken during intervals of pulses of neutron incidence. The authors thank G.B. Yankov for participating in the discussion. Figures 1; tables 3; references 6.

Describing Cross-Section for Fission of Transuranium Nuclei by Fast Neutrons

[Article by A.V. Ignatyuk, Institute of High-Energy, Obninsk, and V.M. Maslov, Institute of Nuclear Power, BSSR Academy of Sciences]

[Abstract] A statistical model is constructed which would describe the cross-section for fission of U and Pm, Am, Cm nuclei by 2 - 20 MeV neutrons on the basis of experimental data pertaining to nuclei of $^{232-238}$U and $^{238-244}$Pu, $^{241-244}$Am $^{242-248}$Am isotopes, considering that the energy dependence of fissionability $P_f(E)$ can be determined from the energy dependence of the cross-section variation $\Delta\sigma_{nf}(E)$. These data indicate that the slope of this dependence decreases with increasing atomic weight of U isotopes until a plateau is reached for ^{238}U and increases with an increase in atomic weight of Pu and Cm isotopes. The derivative dP_f/dE is accordingly negative for ^{236}U and negative for ^{239}U but positive for ^{239}Pu (becoming negative only for ^{245}Pu). The different trends of this dependence are evidently associated with collective shell and superfluidity characteristics of the various nuclei, also with the asymmetry of outer saddle configurations and with axisymmetric inner saddle of light U nuclei. The fission cross-sections above the thresholds of the respective (n,nf) reactions have been calculated on this basis, the fission cross-section depending on both the mass number of a target nucleus and on the energy of incident neutrons. Also, the fraction of a measurable fission cross-section due to the first

chance $\alpha_1 = \sigma_{nf}^1/\sigma_{nf}$ has been calculated. The results are compared with available data from many sources. Figures 8; references 47.

New Method of Determining Mass of Light Nuclides and Quantum Characteristics of Corresponding Nuclei

[Article by I.V. Polavskiy, Odessa Institute of Civil Engineering]

[Abstract] A semiempirical method is proposed for estimating the mass of light nuclides, namely by applying the rule of energy equivalence of fission and decay which the author has established earlier for terms of isobaric multiplets. This rule follows from the theory of the complex Coulomb interaction constant, which is elaborated here by demonstrating that the total Coulomb energy $E_C(A,T,T_z)$ or total mass $M(A,T,T_z)$ depends linearly on the isospin projection T_z or that Coulomb interaction constant. By this method have been calculated not only M - A and J^π of 20 light nuclides with mass numbers $A \leq 64$ (^{39}Sc, $^{42-44}V$, $^{46-48}Mn$, ^{48}Fe, $^{50-52}Co$, ^{52}Ni, $^{55-56}Cu$, ^{56}Zn, $^{58-60}Ga$, ^{60}Ge, ^{64}Se) but also quantum characteristics of the corresponding nuclei. This method is more accurate than the Garvey-Kelson method and much simpler, not involving recurrence relations with a huge number of parameters. It also offers the possibility of checking the estimate of the mass by control calculations, namely by splitting Q into Y and x in various ways. Tables 1; references 26.

Experimental Study of Mass and Energy Distributions of Fission Fragments From Excited Nuclei With $Z^2/A = 33 - 42$

[Article by S.M. Lukyanov, Yu.E. Penionzhkevich, and V.S. Salamatin, Joint Institute of Nuclear Research, Dubna, M.G. Itkis, V.N. Okolovich, and A.Ya. Rusanov, Institute of Nuclear Physics, KaSSR Academy of Sciences, G.N. Smirenkin, Institute of Power Physics, Obninsk, G.G. Chubaryan, Yerevan Institute of Physics]

[Abstract] An experimental study was made concerning mass and energy distributions of fission fragments from target nuclei of W to Pu, with $Z^2/A = 33 - 42$, excited by 97 MeV ^{12}C, 128 MeV ^{16}O, 154 Mev ^{20}Ne ions. Each ion beam was extracted from the U-400 accelerator in the Nuclear Reactions Laboratory at the Joint Institute of Nuclear Research. Fission fragments were recorded with the aid of position-sensitive Si(Au) semiconductor detectors. The masses M_3,M_4 and the total kinetic energy $E_k = E_3 + E_4$ of fragments were then calculated by the correlation method involving solution of a system of four equations for those four unknowns. The readings have been evaluated with the involvement of nine parameters

characterizing the fission processes: 1) fissionability according to the simple model of a liquid droplet with distinct boundary, 2) excitation energy for compound nucleus formed by merger of ion and target nucleus, 3) critical (maximum) angular momentum imparted to compound nucleus in a quasi-classical momentum distribution, 4) mean-square angular momentum imparted to a nucleus undergoing fission, 5) temperature of initial compound nucleus at saddle point, 6,7) average numbers of neutrons emitted before fission and from fragment respectively, fast neutrons from fragment, 8,9) two parameters characterizing insensitivity of nuclei undergoing fission to mass-asymmetric form variations, the second parameter being the second derivative of potential energy with respect to mass-asymmetric deformation. The data, which include the yield of (n,i) reactions depending on the sum $\theta_3 + \theta_4$ of the two divergence angles in the center-of-mass system of coordinates as well as the masses and the energy, have been processed systematically by the standard method. As results have been obtained, the first two moments, the mean and the dispersion, of both mass and energy distributions of fragments from fission of each particular nucleus covered in this study. The dispersions of both distributions are found to increase with increasing mass of fissionable nucleus. The authors thank B.I. Pustylnik, Yu.A. Muzychko, and Yu.A. Lazarev for fruitful discussions and valuable advice. Figures 8; tables 1; references 46.

Search for Superheavy Magnetic Monopoles in Deep-Water Experiments on Lake Baikal

[Article by L.B. Bezrukov, I.A. Belolaptikov, E. V. Bugayev, M.D. Galperin, Zh.A.-M. Dzhilkibayev, G.V. Lomogatskiy, A.A. Doroshenko, A.M. Klabukov, S.I. Klimushin, A.I. Panfilov, I.A. Sokalskiy, and I.I. Trofimenko, Institute of Nuclear Research, USSR Academy of Sciences, N.M. Budnev, V.L. Zurbanov, M.I. Nemchenko, V.A. Poleshchuk, and A.A. Shestakov, Scientific Research Institute of Applied Physics at Irkutsk State University, V.B. Kabikov, L.A. Kuzmychev, and Yu.V. Parfenov, Scientific Research Institute of Nuclear Physics at Moscow State University]

[Abstract] A deep-water search for superheavy magnetic monopoles, according to both minimal and supersymmetric SU(5) models and also the SO(10) model, was conducted over the 1984-89 period in Lake Baikal with "GIRLANDA-84,86,86M" Cerenkov detector sets sunk down to 1380 m deep, 3500 m off the shore, spaced apart over a horizontal distance of 900-1200 m distance so as to cover an area where the absorption coefficient at the maximum-transmittance wavelength within the transparence window was only about 0.05 m^{-1} and the intrinsic glow of water was the sole source of background light. The apparatus of "GIRLANDA-84" included a pair of photomultipliers, searching for slow monopoles between a pair of transparent luminaires made of acrylic glass lamps and a pair of recording devices. In the

"GIRLANDA-86,86M" apparatus one four-stage muon telescope was followed by a line of six monopole detectors and one four-stage muon telescope was placed in line between two monopole detectors. Electronics in "GIRLANDA-84" consisted of two integrated-circuit amplitude discriminators with a 0.2 A threshold (A - average amplitude of one-photon pulses) in parallel feeding a common operational amplifier followed by a sliding time gate (at least 12 pulses per 500 μs), while in "GIRLANDA-86,86M" each of the two amplitude discriminators was feeding a separate pulse repetition rate divider (into 1/32) followed by a sliding time gate (at least 3 pulses per 500 μs). The measurements made with these GIRLANDAs under open water in the steady-state mode were based on the premise that the aperture of underwater Cerenkov detectors is determined principally by the cross-section for catalysis of baryon decay by monopoles and by the optical properties of ambient medium, not being dimensionally limited as is the aperture of underground detectors. They facilitate a more effective search for slow monopoles with large catalysis cross-sections from 10^{-22} cm^2 up, as well as for other particles such as quark nuggets which generate a high-intensity light flux during their passage through water. Underground in the lake bed, on the other hand, with more recording channels per unit volume of active medium it is possible to record slow monopoles even in the absence of catalysis. The authors thank V.A. Rubakov for discussing problems of catalysis, S.P. Mikheyev for discussing the results of these underwater experiments, B.A. Tarashchanskiy for making available his data prior to their publication, E.A. Osnova for assisting in calculations, the entire staff of the three institutions collaborating in development, construction, and operation of "GIRLANDA-84,86,86M", also all organizers and participants of winter (1987-88, 1988-89) expeditions to Lake Baikal. Figures 6; tables 1; references 29.

Physics of Dark Matter in Universe According to Theory of Broken Generational Symmetry

[Article by Z.G. Berezhiani, Institute of Physics, GSSR Academy of Sciences, Tbilisi, and M.Yu. Khlopov, Institute of Applied Mathematics, USSR Academy of Sciences, Moscow. Special Astrophysical Observatory, USSR Academy of Sciences]

[Abstract] The relation between unified theories and corresponding cosmological scenarios as well as the dependence of their physical and astrophysical manifestations on the magnitude of the symmetry violation energy scale v_H (GeV) are schematically analyzed. Cosmological consequences of the gauge theory of broken generational symmetry SU(3)$_H$ combined with global Peccei-Quinn U(1)$_H$ symmetry is specifically being considered. With a redefinition of the scale v_H as the set of scales of hierarchically related successive violations of the SU(3)$_H$XU(1)$_H$ symmetry, a model is constructed which covers all three forms of dark matter (hot, cold, unstable) and according to which that scale determines the dominance of one or another. On this basis is calculated the dependence of the total cosmological density of modern Universe equal to the sum of the following—a-particle density plus tau neutrino density plus muon neutrino density plus electron neutrino density plus baryon density on the scale v_1 of the first symmetry violation, taking into account Majorana neutrino masses as well as neutrino transitions with archyon emission. Six possibble scenarios are considered—one with axyon as the a-particle corresponding to cold dark matter and its dominance, one with ultralight aryon as a-particle and stable neutrinos corresponding to hot dark matter, and four possibilities involving unstable neutrinos with dominance of either their relativistic or nonrelativistic decay products. With axyons v_1 has a lower bound, namely astrophysical estimates of energy lost by stars such as Supernova 1987A due to axyon emission (red giants with $v_1 > 10^6$ GeV). With aryons, v_1 has a lower bound 10^5 GeV, owing to suppression of a γ-interaction as well as of aryon-electron and aryon-nucleon interactions, while the upper bound extends to 10^{14} GeV. The authors thank A.A. Anselm, J.V.F.Vallet, P.V. Vorobyev, A.G. Doroshkevich, V.K. Dubrovich, G.T. Zatsepin, and A.A. Homeriki for valuable discussions. Figures 1; references 38.

Mass Hierarchy of Fermion Generations

[Article by I.T. Dyatlov, Leningrad Institute of Nuclear Physics, USSR Academy of Sciences]

[Abstract] A possible scenario of nonperturbative phenomena is proposed explaining the large differences between the masses of successive fermion generations. This scenario, which involves anomalies in interactions of a (pseudo)vector boson Z' with gauge bosons, leads to a quantitative mass model of fermion generations, based on each generation, forming almost the same condensate diagonal with respect to up and down quark flavors. The model includes interactions of outer fermions, the Z'-currents of massless ones being retained in large longitudinal Z'-fields and transverse gauge fields. On the basis of this model, the masses of physical fermion states and then the quark mixing matrix are evaluated. Neutral transitions from one fermion generation to another, a key problem for any theory beyond the standard model, are analyzed according to this model with the aid of experimental data pertaining to such transitions as weak-interaction but not yet confirming the smallness of their interaction constants. Conversion of the model into a relativistic theory is considered next, several properties of the model need to be established first and several problems need to be resolved in this connection. Inasmuch as vector boson Z' has a mass, not as a consequence of broken gauge invariance, the Z'-field having no gauge symmetry, but owing a much simpler mechanism of possible shift of "bare" mass. If that mass is

large, say from 1 TeV up, then the model will be a phenomenologically valid one as long as the shift of mass is due to a nonperturbative phenomenon. Another possible problem is Goldstone states arising with spontaneous violation of the equality for the condensate density matrix, possibly by breaking of the chiral $SU(2)_L$ symmetry, or by spontaneous breaking of index i = R,L retention by fermion generations, or by spontaneous breaking of approximate symmetries. Each possibility is weighed by calculation of the corresponding mass scale. Since a Goldstone broken $SU(2)_L$ symmetry state ensures that W and Z particles have a mass, the lepton part of this state being a weak doublet with Y = 1, which demonstrates the possibility of experimentally establishing that the relation $M_W{}^2 = M_Z{}^2 \cos^2\theta_W$ holds true. Violation of this relation could be caused by weak corrections to quark condensates such as inequality of $Y_R{}^u$ and $Y_R{}^d$ or by a new heavy Z'-boson mixing with other neutral vector bosons. The author thanks Yu.L. Dokshitzer for substantial assistance and Ye.M. Pavlenko for working on the manuscript. Figures 7; references 19.

UDC 538.0

Anomalous Magnetic Moment of Electron and Synchrotron Radiation

[Article by I.M. Ternov, V.A. Bordovitsyn, and V.Ya. Epp, Tomsk Pedagogical Institute imeni Lenin Komsomol]

[Abstract] The characteristics of synchrotron radiation emission by an ultrarelativistic electron are analyzed and evaluated in the quadratic approximation of relativistic semiclassical electrodynamics, which takes into account the anomalous quadratic with respect to $\tilde{\epsilon} = \hbar\tilde{\omega}/E'$ (h - Planck constant) magnetic moment of such an electron but ignores second-order effects of recoil and mixed radiation emission. First is considered radiation emission with spin flip, its spectral-angular distribution being calculated in terms of Airy functions for an electron with a small anomalous magnetic moment. A special case is an electron polarized parallel to the magnetic field, the estimated self-polarization time indicating that its anomalous magnetic moment merely facilitates ordering the orientation of its spin during radiation emission. References 14.

New Method of Recording Photoionization of Oriented Molecules

[Article by A.V. Golovin, V.V. Kuznetsov, and N.A. Cherepkov]

[Abstract] A new method of recording photoionization of oriented molecules, with an electron detector and an ion detector, is demonstrated on dissociative photoionization of O_2 oxygen molecules in the ground state $^3\Sigma_g{}^-$. The axis of a molecule along which its atom and ion disperse is perpendicular to the direction of propagation of incident nonpolarized light and photoelectrons which are recorded in a plane perpendicular to that direction. The angular distribution of the differential cross-section for photoionization of an adsorbate molecule, obtained on the basis of measurements by this method, agrees closely with the theoretical angular distribution of photoelectrons knocked out from such a molecule by nonpolarized incident light. The latter is calculated in the electric dipole approximation and following a series expansion of the photoelectron wave function into partial waves. Figures 2; references 3.

Quantum-Chromodynamical Parametrization for Structural Deep-Inelastic-Scattering Functions

[Article by V.I. Vovk, A.V. Kotikov, and S.I. Maksimov, Institute of Theoretical Physics, UkSSR Academy of Sciences]

[Abstract] The asymptotic behavior of structural deep-inelastic-scattering functions $F(x,Q^2)$ as $x \to 1$ and $x \to 0$ is predicted, for nonsinglet quark distributions in a nucleon, not by differentiating the Mellin transforms of their moments $M(n,Q^2)$ = Integral of $x^{n-2}F(x,Q^2)dx$ from x = 0 to x = 1 and then directly solving Altarelli-Parisi-Lipatov integrodifferential equation obtained by convolution of the Mellin transforms, but by quantum-chromodynamical parametrization of the moments with the aid of a function f(x) defined on the [0,1] interval and having moments g(n) = Integral of $x^{n-2}f(x)dx$ with $n > n_0$ ($n_0 < \infty$). Then the principal terms of the asymptotic expansions of function f(x) will be respectively f(x) = (1 - x)sup$c$L(1 - x) (c > 0) as $x \to 1$, where l(t) and L(t) are functions slowly varying at infinity for x = 0 only when $g(n)(N \to 0) = N^{-b-1}l(1/N)\Gamma(b + 1)$ as N = n + a - 1 $\to$ 0 and/or $g(n) = N^{-c-1}1L(1/N)\Gamma(c + 1)$ for n = N. Subsequent parametrization according to Buras-Gaemers (NUCLEAR PHYSICS Vol BB2 Nos 3-4, 1980) is proposed, not only for quantitative description of the experiment, but also for qualitative reconciliation with the QCD theory. Assuming that the obtained function $F_p(x,Q^2)$ satisfies the Altarelli-Parisi-Lipatov equation exactly in the principal terms of the asymptotic expansions as $x \to 0$ and as $x \to 1$, the asymptotic behavior of its parameters is evaluated analytically. The anomalous dimensionality d(n) is equal to zero for n = 1 so that G = Integral of $F(x,Q^2dx/x)$ from x = 0 to x = does not depend on Q^2 in the leading order, which represents rules of sums: Adler rule for $F_2{}^{NS}(x,Q^2)$ with G = 1/6 and Gross (Llewellyn-Smith) rule for $xF_3(x,Q^2)$ with G = 3. References 23.

Parameters of Optical Waveguides on LiNbO$_3$:Ti or LiTaO$_3$ and Their Dependence on Composition of Crystal

[Article by V.V. Atuchin and K.K. Ziling, Institute of Semiconductor Physics, Siberian Department, USSR Academy of Sciences, Novosibirsk]

[Abstract] Synthesis of optical waveguides by diffusion of titanium into LiNbO$_3$ or LiTaO$_3$ crystals are considered. The profiles of both ordinary and extraordinary refractive index increments are considered, depending on the diffusion coefficient D at a given temperature as well as on coefficients A_o and A_e relating the molar fraction of Ti to those increments Δn_o and Δn_e respectively. This dependence, specifically on the stoichiometry of the original crystals, is analyzed theoretically on the basis of an experiment involving Ti films on Z-cut LiNbO$_3$ and LiTaO$_3$ crystals. Waveguides were constructed by diffusion of Ti from 78 nm thick films into the substrates, into LiNbO$_3$ substrates at 980°C for 8 h in air and into LiTaO$_3$ substrates at 1260°C for 10 h in air. The birefringence Δn^* of the substrates and the two effective refractive indexes N_m of the waveguides were measured in light of 0.63 μm wavelength entering through a prism. The chemical composition of the substrates was then determined on the basis of their birefringence and both index increment profiles in a waveguide were reconstructed by the inverse Wentzel-Kramer-Brillouin method from its two refractive indexes. The results reveal a similar inverse-law dependence of D on the molar fraction z of lithium in both crystals. Considering that the increments of both indexes are known to be proportional to the molar Ti:Ta = y ratio, Δn_e being also proportional to the molar Ti:Nb = y ratio and Δn_o increasing linearly only from y = 0.7 mol.% on, possible mechanisms responsible for the dependence of both coefficients A_o and A_e on z are sought on the basis of theoretical analysis and numerical estimates. Neither the change in refraction due to injection of Ti-impurity, nor the elastooptic effect are found to be significantly influential. The principal mechanism is evidently the slow drop ΔT_C of the Curie temperature as the Ti content in LiNbO$_3$ crystals with a low Li content (z = 0.486 - 0.5) increases with an attendant still fast increase of spontaneous polarization, its contribution to both A_o and A_e being proportional to $\Delta T_C/y$. No reliable experimental data on LiTaO$_3$:Ti crystals pertaining to the dependence of $\Delta T_C/y$ on z are available, but there is evidence that these trends are essentially similar in this system. Figures 2; references 19.

Theory of Planar Waveguide as Separator of Spectral Channels

[Article by A.S. Starkov, Leningrad Institute of Technology for Refrigeration Industry]

[Abstract] A planar waveguide is considered for separation of spectral channels, this is possible in an asymmetric dielectric waveguide with smoothly decreasing thickness of the waveguide layer, but only when its cross-section remains larger than critical for all modes except the one being successively cut off. Theoretical design and performance analysis of such a simultaneously bending and tapering waveguide requires calculation of its radiation pattern for waves of a mode at its critical exit cross-section. Calculation of that radiation pattern is based on the scalar wave equation $(\Delta + k^2 n_i^2 u_i = 0)$ in the system of coordinates s,v (s - longitudinal curvilinear coordinate, v - radial-normal coordinate, Δ - Laplace operator, n_i - refractive index of i-th medium, $u_i(s,v)$ - scalar function of both coordinates, i = 1,2,3) with two boundary conditions reflecting the condition of continuity for tangential field components at the converging dielectric-air boundary and dielectric-substrate boundary respectively, these boundary conditions involving the ratio $(n_2/n_1)^r$ with r = 0 for S-Polarization and r = 2 for P-polarization. Figures 2; references 4.

Phase Modulation and Mode Coupling in Dual-Mode Optical Fibers

[Article by O.I. Kotov, O.L. Marusov, and V.M. Nikolayev, Leningrad Polytechnic Institute imeni M.I. Kalinin]

[Abstract] An experimental study of coherent optical fibers for communication lines or instrument transducers was made concerning the effect of lossy bends on the phase of transmitted light waves. Coherent light from a He-Ne laser was passed through such coils of optical fibers, not wound on bobbins, but flattened by squeezing into a special micrometer so that straight segments alternated with approximately semicircular bent ones. Changes of phase were indicated by interference of modes at the fiber coil exit, modes having interacted while passing through the bent fiber segments. Theoretical analysis of the interaction of modes based on consideration of two modes and assumption of a constant mode coupling coefficient, which in this case is k(r) = 0 along the straight segments and k = k(r) along the bent segments depending on the radius of the semicircle. This indicates an exchange of energy between coupled modes with attendant changes in the length of the interaction zone and in the relation between their phases. Change in the length of the interaction zone causes the propagation constant of the two modes to differ, the difference Δ being measurable on the basis of light intensity readings at the fiber coil exit. Change in the relation between the phases results in differential phase modulation, inasmuch as the phases of the two modes shift in opposite directions: one forward and one backward, the magnitudes of the two phase shifts being equal and proportional to $k(r)^2/\Delta$. In a special experiment, harmonic phase modulation was attained by varying the radius of

fiber curvature at frequencies up to 1 kHz with the aid of a piezoceramic or electromechanical transducer. Phase modulation in the bends was found to cause the light intensity at the fiber coil exit to fluctuate but not to monotonically decrease by more than 5 percent, the depth of phase modulation also varying but remaining larger with a shorter period than amplitude and polarization modulation. Figures 2; references 5.

Behavior of Effective Charges in Curved Space With Boundaries

[Article by S.D. Odintsov, Tomsk Pedagogical Institute imeni Lenin Komsomol]

[Abstract] New effective charges in curved space with boundary δM which have no analogs in flat space are considered, their behavior being analyzed on the basis of the $\lambda \psi^4$ theory in such a space where quantum fluctuations of the scalar field satisfying either Dirichlet or Robin boundary conditions. This theory is asymptotically free at time $t \to -\infty$ and the principal effective charges are found to be $\alpha_D(t)$, $\beta_D(t)$, $\zeta_D^{(1)}(t)$, $\alpha_R(t)$, $\beta_R(t)$, $\mu_R(t)$, $\nu_R(t)$, $\sigma_R(t)$, $\zeta_R^{(1)}(t)$. At time $t \to +\infty$ the problem reduces to the zero-charge problem, but for $\lambda < 0$, the theory becomes unstable with a formal limit existing and the same effective charges being the principal ones. References 11.

Nonreciprocal Optical Effect in Interaction of Light and Traveling Permittivity Wave

[Article by G.Ye. Zilberman, L.F. Kupchenko, Yu.V. Astashev, V.Yu. Vdovenkov, G.F. Goltvyanskaya, I.N. Goltvyanskiy, and M.V. Cherenov]

[Abstract] Interaction of two counterpropagating light waves and a traveling permittivity wave is analyzed, namely their diffraction by the latter, considering that the amplitudes and the phases of their respective zeroth diffraction order are different as a consequence of different conditions of Bragg synchronism for the two light waves. Maximum amplitude nonreciprocality, and thus maximally different diffraction efficiency, is attainable with a sufficiently large nonreciprocality parameter $\nu = 2cn_ok_o/c_ok$ (c,k - speed and wave number of permittivity wave, n_o - optical refractive index of dielectric medium, c_o,k_o - speed and wave number of light waves) or with a sufficiently long interaction space for counterpropagating light waves in the diffraction grating formed and moved by the permittivity wave. This sufficient length of

the interaction space is shown to be smaller than for interaction with a traveling ultrasound wave, inasmuch as the ratio c/c_o is larger and does not depend on the elasticity of the material as it does in the case of an ultrasound wave. A traveling permittivity wave can be generated in a dynamic recording medium by superposition of two noncollinear optical waves with different frequencies. This was experimentally done using SiC as the medium, with a refractive index $n_o = 2.63$ and a recording + erasure time $\tau = 10$ ps. Here a 0.05 cm long interaction space was sufficient for maximally nonreciprocal interaction with a 100 GHz traveling permittivity wave, as compared with a 6.5 cm long interaction space in sapphire necessary for maximally nonreciprocal interaction with a 1 GHz traveling acoustic wave. Figures 1; references 6.

Spectra of New Series of Ferroelectric Liquid Crystals: Esters of Diphenylcarbonic Acid

[Article by T.P. Myasnikova, N.I. Chernova, and M.V. Loseva, Rostov University]

[Abstract] An experimental study of a recently synthesized new series of liquid crystals, 4-alkyloxyphenolic esters of 4'-(2-methylbutoxycarbonyl) diphenylcarbonic acid with an OC_nH_{2n+1} link at one end of the chain, was made in regard to the spectral characteristics of the homologs with n = 5,6,7,8,10 existing in a ferroelectric smectic phase SmC*, each within certain temperature ranges. Transition of these homologs from their initial solid crystal C-phase to their smectic SmC*-phase is followed by transition from that smectic SmC*-phase through intermediate phases to the isotropic liquid phase I, that of homologs n = 5,6,7 through three intermediate phases (smectic SmA $\to$ cholesteric $\to$ blue) and that of homologs n = 8,10 through only one intermediate phase (smectic SmA), each transition occurring at a different critical temperature different for each homolog. Their luminescence excitation, luminescence, and absorption spectra were measured at temperatures within the respective ranges of existence of their C, SmC*, SmA phases, covering all together the 320 - 580 nm range. The half-width of each luminescence band ΔE_{lum} and the known Stokes shifts ΔE_S were used for calculation of the effective phonon energy $h\omega = 0.363\Delta E_{lum}^2/\Delta E_S$. The average phonon energy is accordingly 150 meV, which corresponds to a frequency of 1212 cm^{-1} and is somewhat lower than 180 meV or 1450 cm^{-1} based on the distance between luminescence intensity peaks. Resolution of the luminescence spectrum of the homolog with C_7H_{17} into five components had made it possible to regard the phonons as electron-vibrational transitions and to calculate their frequencies. The results are interpreted by referring to the known spectra of the C-phase

and of a 2.5 percent C_7H_{17} solution in CCl_4. Considering that molecules of this homolog and of all the others contain two $C = O$ groups and weak $C = O...H-C$ bonds each, their $C = O$ vibration absorption spectra evidently include bands corresponding to ionic complexes with proton transfer as well as bands corresponding to complexes with intramolecular and intermolecular hydrogen bonds. Figures 2; tables 1; references 7.

UDC 621.373.826

Propagation of Light Soliton During Adiabatic Tracking at One-Photon Resonance

907J0085H Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 17 No 6, Jun 90 pp 763-766

[Article by V.D. Gora, Moscow Institute of National Economy imeni G.V. Plekhanov]

[Abstract] A soliton solution is found to be the problem of light propagating through a medium at quasi-resonance when the carrier frequency of the quasi-monochromatic light pulse packet does not significantly differ from the frequency ω_{21} of transitions from quantum state 2 to quantum state 1 in the medium, but the difference is larger than the spectral width of the light band and the response of the medium tracks adiabatically any changes in the electric field of that light pulse packet. The wave equation for the complex amplitude of this electric field is formulated in the second-order approximation of the dispersion theory. The state of the medium is described by two differential equations in the two-level approximation, one for the rate of change of the density matrix element σ_{12} and one for the rate of change of the difference between populations of quantum states 1 and 2. Both the Stark effect and polarization reversal are assumed to be negligible in a medium where particles have a different linear polarizability in each state. Upon introduction of the "local" time and dimensionless coordinates, the solution to that wave equation is solved exactly for the initial condition and the boundary conditions corresponding to a soliton. Saturation of the resonance transition is for the first time taken into account, it is expressed by the ratio of the saturation intensity to the peak intensity of the light packet. Expressions are obtained on the basis of this solution for the duration and the critical energy density of a soliton, whereupon the behavior of Gaussian light pulses, depending on their energy density, is analyzed by the method used for analysis of resonant self-focusing. Inasmuch as increasing the pulse energy increases the pulse intensity so that the nonlinearity of the medium diminishes, owing to saturation, hardly any pulse self-focusing occurs when the dispersion length is shorter than some "nonlinearity" length and two critical energy densities $W_{c1} > W_{c2}$ exist when the dispersion length is longer. In the latter case pulses with an energy density higher than the upper critical propagate as strong quasi-solitons and their duration oscillates between the initial and a minimum one, while pulses with an energy density

between the two critical ones propagate as weak quasi-solitons and their duration oscillates between the initial and a maximum one. Pulses with an energy density equal to the upper critical exist as quasi-solitons of steady duration. Pulses with an energy density equal to the lower critical become diffused. The author thanks A.P. Sukorukov for discussion and comments. Figures 3; references 15.

UDC 621.373.826

Formation of Reflecting Surface of Adaptive Mirror Conjugate to Wavefront Distortions

907J0085I Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 17 No 6, Jun 90 pp 786-792

[Article by V.V. Apollonov, Ye.A. Ivanova, A.M. Prokhorov, and S.A. Chetkin, Institute of General Physics, USSR Academy of Sciences, Moscow]

[Abstract] The response functions of an adaptive mirror, a thin disk constrained around its periphery and supported by a finite number of actuators conjugating the mirror surface to distortions of the incident wavefront, is analyzed on the basis of experimental data and a physical model for numerical analysis. The experiment was performed with such a mirror resting on five actuators made of PKR-6 polarized piezoceramic, one at the center and four equally spaced 90° in a small circle around it. Formation of the reflecting surface under static and dynamic conditions was monitored by means of a stroboscopic Fizeau interferometer operating with $\lambda = 0.6328$ μm light, the interferograms having then been processed so as to reconstruct the shape of the mirror surface in any cross-section with an error not larger than $\lambda/20$. The mirror's amplitude-frequency and phase-frequency characteristics were measured with an eddy-current transducer of nonsteady displacements in a vibration stand. Its optical surface was controlled by means of those piezoceramic actuators, "depolarization" with an alternating current of steadily decreasing amplitude being necessary for removing the hysteresis from their transfer characteristic. The operating frequency range of the mirror was 0 - 5 kHz. The sensitivity of each actuator was 5.3 μm/kV and thus five times lower than in the "free body" state. The performance analysis of this system is based on the physical model of a thin plate with a continuous reflecting surface on five free discrete supports and with a continuous fixed peripheral constraint, according to the theory of thin plates in the approximation of small displacements relative to the plate thickness. This model is analyzed for accuracy, whereupon the performance of actuators is analyzed by the method of least squares for accuracy of correction of primary mirror aberrations. The results of calculations and of the experimental study validate this model. The effectiveness of aberration correction in terms of mean-square mirror compensation error, depending on the number and the spacing of actuators as well as on the conditions of light beam incidence on the mirror surface,

is then estimated on the basis of numerical simulation. The authors thank V.I. Andryushin, G.A. Zhitomirskiy, and V.V. Ostanina. Figures 9; tables 1; references 13.

Convective Stability of Superfluid ^{3}He-^{4}He Solution

[Article by A.P. Grigin, All-Union Scientific Research Institute of Current Sources]

[Abstract] Natural convection in a superfluid liquid weak solution of ^{3}He in ^{4}He under gravity at temperatures below the lambda point is reexamined and analyzed for the stability limit, the system of five Landau-Khalatnikov equations which describes it in the Boussinesq approximation which includes the density of Archimedean buoyancy forces. This system of equations is solved for the nonequilibrium state of a plane horizontal superfluid layer with a temperature jump at the solid-liquid interface. With an appropriate redefinition of the Reynolds number, the Rayleigh-Benard problem of steady convective instability is reduced to the problem of convective instability in a normal liquid so that the critical Reynolds number characterizing the limit of steady natural convection and calculated with the proper multiplier will be consistent with experimental evidence. References 12.

UDC 535.375

Pulse Compression and Effective Reflection Coefficient During Stimulated Backscattering

[Article by A.P. Vinnichenko and V.I. Kislenko, Kiev University imeni T.G. Shevchenko]

[Abstract] Time compression of a laser pulse during stimulated backscattering in a medium bounded by two parallel planes $z = 0$ and $z = L$ equal to (approximately) or larger than $T_0 v/s$ (T_0 - pulse duration, v - pulse velocity), is analyzed on the basis of the solution to two simultaneous first-order partial differential equations of radiation transfer in space and time from a laser pulse of intensity $I_1(z,t)$ to a Stokes pulse of intensity $I_s(z,t)$. The first equation describes the decrease of laser radiation intensity and the second equation describes the increase of Stokes radiation intensity upon "reflection" of the laser pulse within such a medium with an effective (normalized to unit length) reflection coefficient. These equations cover any kind of stimulated backscattering by fluctuations, generally as well as stimulated Raman and Mandelshtam-Brillouin scattering. The solution to both equations with the respective set of boundary conditions for the intensities of pulses at $z = 0$ and $z = L$ leads to the Fredholm integral equation of the first kind for the

reflection coefficient. In the approximation of equal laser pulse and Stokes pulse velocities as well as equal reflection coefficients for laser and Stokes radiation, this equation has been solved numerically for the space-time distributions of laser radiation intensity, Stokes radiation intensity, and the effective reflection coefficient. Calculating the effective reflection coefficient $R(z)$ at successive instants of time required regularization, which was done by the Tikhonov method, this being an ill-conditioned inverse problem for that Fredholm equation in the given approximation. The results, confirmed by oscillograms of stimulated Mandelshtam-Brillouin backscattering, indicate that the region of effective scattering with attendant pulse compression shifts in time from the $z = L$ rear plane toward the $z = 0$ front plane of incidence, the degree of pulse compression being determined by the velocity at which the characteristic region of radiation transfer from incident pulse into scattered waves moves from $z = L$ toward $z = 0$. The condition that L be approximately equal to or larger than $T_0 v/2$ for pulse compression to take place is equivalent to the requirement of synchronous exit from plane $z = 0$ of radiation returning from the region just behind $z = 0$ and from the region just in front of $z = L$. The authors thank A.I. Zhizhnyak and Yu.N. Yashkir for discussing the results. Figures 1; references 13.

Electromagnetic Wave Intensity Probability Distribution in Area of Wide Fluctuations

[Article by R. Kh. Almayev, A. A. Suvorov, Tayfun Scientific Production Association]

[Abstract] Electromagnetic wave propagation in media of various nature with dielectric constant fluctuations is accompanied by cumulative random wave phase and amplitude variations whose magnitude and distribution are determined by the medium parameters and path length. The discrepancy in the behavior of theoretical and experimental intensity fluctuation variation distributions, or the so-called lognormal paradox, is examined. Based on a calculation of the n-th radiation intensity distribution moment modified for the case of the wave propagation in a turbulent medium with both real and imaginary ε component fluctuations, the $P(I)$ function which is adequately consistent with experimental data is derived in the article. It is shown that as a result of taking into account this random wave attenuation by fluctuations of the ε imaginary component, the consistency of theoretical and experimental results may be improved. References 8: 4 Russian, 4 Western; figures 2.

Photostimulated Gyrotropism and Photostimulated Light Scattering in As$_2$S$_3$3 Chalcogenide Glass

[Article by V. M. Lyubin, V. K. Tikhomirov, Engineering Physics Institute imeni A. F. Ioffe at the USSR Academy of Sciences]

[Abstract] The high photostimulated activity which characterizes the photostimulated anisotropy (FA) in the As_2S_33 glass and the accompanied transformation of plane-polarized light into elliptically polarized described in the authors' earlier study cannot be attributed solely to linear dichroism and birefringence. It enabled them to speculate that in addition to FA, the samples also displayed photostimulated gyrotropism, i.e., circular dichroism and circular double refraction. An integral chalcogenide glass sample was exposed to intense He-Ne laser radiation with a quantum energy under 2.3 eV. As a result, circular dichroism and a considerable light scattering were detected, making it possible to attribute these phenomena to the production of anisotropic and gyrotropic scatterers under the effect of irradiation and confirming the authors' earlier theory. References 7: 6 Russian, 1 Western; figures 3.

UDC 533.951

Speed of Nuclear Reactions With Anisotropic Distribution of Interacting Particles

[Article by V.S. Imshennik, Institute of Theoretical and Experimental Physics]

[Abstract] Binary thermonuclear fusion reactions with an anisotropic distribution of interacting particles are considered, the Boltzmann double integral describing the speed per unit volume of any binary reaction being transformed into the product of two integrals: integral of their relative speed $g_{12} = c_2 - c_1$ and integral of the speed of their center of inertia $G = (m_1 c_1 - m_2 c_2)/(m_1 + m_2)$. The distribution function, analogous for the particles of the two generally different reactants, is the sum of two functions describing their distribution in the stationary "target" and in the incident "beam" respectively. Both components are assumed to decrease exponentially with increasing kinetic energy and decreasing temperature. Each exponential function is multiplied by the concentration of the corresponding particles and by the three-halves power of half their mass divided by π times their temperature. Both initial temperature and "beam" velocity are, moreover, assumed to be constant. The second integration is performed over the domain of center-of-inertia speeds and then the first integration is performed over the domain of relative particle speeds. An analytical expression is thus obtained for the speed of binary reactions involving two different kinds of particles in the entrance channel to the interaction space. Binary reactions involving particles of the same kind with identical masses are considered important special cases. References 11.

UDC 533.951.2

Density Solitons and Current Limitation in Electron Beam Current

[Article by B.N. Rutkevich and S.B. Rutkevich, Kharkov Institute of Engineering Physics, UkSSR Academy of Sciences]

[Abstract] The problem of electron beam cutoff with current limitation in a transition horn between two waveguides of different widths is analyzed, an aperiodic instability resulting in formation of a virtual cathode (highest potential and electron beam density) which back-reflects electrons having been shown to develop in a semi-inifinitely long waveguide with metal walls and with the entrance covered by a foil transparent to electrons. An uncompensated thin flat electron beam passing between two long parallel plates in a strong longitudinal magnetic field is considered first, these plates forming a waveguide much wider than the thickness of the electron beam and eventually terminating into a horn. From the two equations of energy and momentum conservation is derived the equation for the beam potential - $2(e/m)\Phi_b/v_1^2 = \Psi = q(1 - \Psi)^{-1/2}$ (Φ - potential of perturbed electron beam relative to waveguide walls, v_b - velocity of unperturbed electron beam at entrance to waveguide, n_1 - electron concentration in unperturbed beam at entrance to waveguide, $2h$ - thickness of waveguide, $2H$ - width of waveguide, e/m - electron charge-to-mass ratio, $\omega_1^2 = 4\pi n_1 e^2/m$, $q = 2\omega_1^2 hH/v_1^2$) which has real roots only for q up to q_c. This critical value of q determines the magnitude of the limiting electron beam current, which corresponds to Ψ_c and thus to the critical potential Φ. Existence of density solitons in a thin electron beam of finite width is then established as solution to the system of three equations of long-wave oscillations, one of them having been derived from the Poisson equation for oscillations with a wavelength much larger than the waveguide width. Such a soliton is treated as an elementary perturbation for momentum calculations. The dependence of its amplitude and energy on its momentum and on the velocity of the unperturbed electron beam is evaluated. Inasmuch as the velocity w of a backward propagating soliton and its amplitude A are found to obey the relation $w = 1 + A/4$, and A cannot be larger than w^2, both parameters have upper criticals $A_c = 4$ and $w_c = 2$ respectively. A soliton with an amplitude larger than 4 will, therefore, reflect electrons so that the single-velocity model ceases to be applicable. Electrons, furthermore, lose velocity in the horn and their momentum is transferred to a soliton. Evolution of a soliton in the horn into a virtual cathode is analyzed next, considering that its amplitude increases linearly with the width of the horn section and also depends on the proximity to the critical horn section where the electron beam loses its stability. Figures 4; references 11.

UDC 533.951

Modulation Instability and Formation of Soliton at Ion-Ion Hybrid Resonance Frequency

[Article by T.A. Davydova and V.M. Lashkin, Institute of Nuclear Research, UkSSR Academy of Sciences, Kiev]

[Abstract] The nonlinear stage of modulation instability at the ion-ion hybrid Langmuir-cyclotron resonance frequency is analyzed in connection with ion-cyclotron plasma heating in a high-frequency electric field. The analysis is based on the system of applicable equations of hydrodynamics and the Poisson equation in the one-dimensional approximation ion-ion hybrid plasma turbulence in a uniform magnetic field, with all variables subject to perturbation resolved into the sum of an aperiodic term with a slowly varying amplitude plus an

infinite series of harmonics with slowly varying amplitudes plus their complex-conjugates. Averaging over the oscillation period at ion-ion hybrid resonance reveals a system of equation for all those slowly varying amplitudes. Under a certain condition representing instability, self-action of the ion-ion hybrid wave associated with second-harmonic generation is found to be the principal nonlinear effect. A second-order nonlinear equation is accordingly obtained describing the dynamics of modulation instability at the ion-ion hybrid resonance frequency. For a monochromatic high-frequency wave with finite amplitude, linearization of this equation yields the increment of buildup and then the modulation instability threshold. This equation is then reduced to two integrable ones which, depending on the form of the "pseudopotential", can have a soliton solution. A soliton in the form of a piecewise-continuous curve such as a cissoid corresponds to a "pseudoptential" with a singularity arising from the lack of a "modulation scale" in the given treatment of the problem. Figures 1; references 4.

UDC 536.71

Wide-Range Equation of State for Water

[Article by A.M. Belyayev, V.S. Vorobyev, and A.L. Khomkin, Institute of High Temperatures, USSR Academy of Sciences]

[Abstract] An equation of state for water is formulated which covers the 0 - 60,000°C temperature range and the 0 - 40,000 atm pressure range. It is based on the Random Network Model, a continuous network of hydrogen bonds, the spectrum of O-H oscillators being described by the distribution function $P(\omega_{OH})$ convenient for calculation of the thermodynamic characteristics. Taken into account are not only dissociation and ionization processes, but also possible nonideality of the vapor and the plasma at high temperature and pressure. First, temperature range below 1000°C is considered, this part of the equation being obtained by splicing the solutions to interpolation equations of state at the limits of their respective validity. The high-temperature part of the proposed equation takes into account the appearance of H_2^+ and O_2^+ as well as H^+ and O^+ ions in the water, the activity of all four charged component and the chemical equilibrium constants of all eight reactions being figured in. The eight equations of chemical equilibria are supplemented with an equation which represents conservation of the relative number of H and O nuclei ($n_H = 2n_O$ law), with the equation of state for 11 components of water (H_2O, H_2, O_2, OH, O, and those four ions), and an equation which represents the condition of electroneutrality. The resulting complete equation of state V = V(p,T) can be transformed into the equation p(V,T), this being done by iterative search for the root p when V is given. Figures 4; references 22.

UDC 533.9

Dielectric Anomaly of Mercury Near Critical Point

[Article by A.A. Likalter, Institute of High Temperatures, USSR Academy of Sciences]

[Abstract] The anomalous increase of the dielectric permittivity of mercury vapor near the critical point is explained by polarization of atoms in percolating clusters in accordance with the Clausius-Mossotti equation applicable to moderately dense metal vapors as well as to dense atomic gases and liquids. The polarizability of atoms with an ns valence shell with a large principal quantum number n in an electric field is determined by the shift of the region available, in the classical sense, for mobility of valence electrons and is, therefore, the same as that of free atoms. As these regions of two atoms overlap, the potential barrier between them vanishes and a virtual valence electron of one atom moves into the other atom without increasing its energy. As the degree of polarization increases, however, the energy of that atom increases according to a square law. The bonds are taken into account by estimating their average number per atom or quasi-molecule with the aid of the complete correlation function $h(r) = g(r) - 1$ for the radial probability distribution of atoms $g(r)$, this number depending on the thermodynamic state and increasing as the compressibility increases. Dispersion of the polarizability is disregarded, inasmuch as the dielectric anomaly was discovered at frequencies far below resonances of a free atom and of the ionic term. The dependence of the permittivity on the density of mercury vapor along the critical isotherm (1750 K) is calculated following regularization of the Clausius-Mossotti equation in the continuous medium approximation, which removes the physically unlikely spontaneous polarization of vapor. Calculation of this dependence near the Mott transition point (1800 K) yields a frequency dispersion of the permittivity. The anomalous peaking of the dielectric permittivity is found to occur far below the Mott transition point, owing to its critical fluctuations. Reflection of light, according to the appropriately modified Drude equation, therefore, becomes intense long before transition to the metallic state. Figures 3; references 13.

UDC 533.92

Evolution of Structure and Parameters of Plasma Jet After Pulsed Plasma Injection Into Atmosphere

[Article by A.P. Yershov, I.B. Timofeyev, S.N. Chuvashev, and S.P. Bytskevich, Moscow State University imeni M.V. Lomonosov]

[Abstract] A jet of plasma pulse-injected into the atmosphere is described in accordance with the theory of turbulent gas jets and the theory of relaxation of a plasma at local thermodynamic equilibrium. Slow injection, with the local Mach number not much higher than 1.0, into the atmosphere in a pulse of approximately 100 μs duration is considered, such a plasma behaving like a continuous medium and forming a jet upon its injection into dense gas such as air. Evolution of the plasma jet in the atmosphere is attended by gas dynamic instabilities, Kelvin-Helmholtz rather than Rayleigh-Taylor instability usually playing the principal role, and involves formation of a spherical or toroidal vortices. For a gas dynamical analysis of the plasma vortex structurization process, it is broken down into its endoergic initial stage of plasma inrush involving air displacement by a "plasma piston" and its later exoergic stage of plasma vortex relaxation as a result of cooling by radiation emission. The analysis is supplemented with an evaluation of the kinetic parameters during the vortex evolution process. The results of the analysis including numerical estimates confirm experimental observations, aided by high-speed photography, namely that toroidal vortex structures in such a plasma jet always have a longer life than spherical ones. Figures 3; references 27.

UDC 538.945

Effect of Dielectrization of Electronic Spectrum on Critical Current in $BaPb_{1-x}Bi_xO_3$ Josephson Materials

[Article by A.I. Voytenko, A.M. Gabovich, D.P. Moiseyev, V.M. Postnikov, and A.S. Shpigel, Institute of Physics, UkSSR Academy of Sciences, Kiev]

[Abstract] The temperature dependence of the critical tunneling current I_c through a symmetric Josephson junction separating two edges of porous ceramic $BaPb_{1-x}Bi_xO_3$ superconductor material is calculated. These materials have a Fermi surface, part of which contains a spin-singlet dielectric gap Σ of collective nature and charge density or spin density waves appearing in them. Calculations and analysis of the results are based on the Bilbro-McMillan model of such a superconductor with partial dielectrization of its electronic spectrum and thus partial degeneracy of the Fermi surface, this dielectric gap coexisting with the only superconductor energy gap Δ found on the entire Fermi surface. The width of this dielectric gap is treated as a temperature-independent constant parameter, this assumption being valid when its width in degrees K is much larger than the critical temperature or when the matrix elements representing single-particle intergranular transitions which render the dielectric gap nonuniform have large values. The temperature dependence of the superconductor energy gap $\Delta(T)$ based on this model of superconductors with charge density or spin density waves deviates appreciably from its temperature dependence according to the Bardeen-Cooper-Schrieffer equation. When normalized to its magnitude at absolute zero temperature, however, its temperature dependence fits the Mühlschegel curve of $\Delta(T)/\Delta(0)$ versus T/T_c almost everywhere with small deviations only within the range of low relative density of electronic states $v = N_{nd}(0)/v_d(0)$ ($N_d(0)$ and $N_{nd}(0)$ denoting the density of electronic states at virtually zero temperature within the dielectrized part of the Fermi surface and within the remaining part of the Fermi surface respectively). Moreover, the absolute value of $\Delta(0)$ and those of $\Delta(T)$ depend strongly on both v and Σ. The temperature dependence of the critical current is then calculated accordingly and found to follow the Ambegaokar-Baratoff equation in the limiting case of a zero dielectric gap. These theoretical results are supplemented with experimental results pertaining to three $BaPb_{1-x}Bi_xO_3$ ceramics with x = 0.15, 0.25, 0.3 respectively. The critical current and the critical temperature were both determined on the basis of electrical resistance measurements, increasing the Bi content having been found to lower the critical current density much more than the critical temperature. On the basis of these measurements was also determined the dependence of the dimensionless energy parameter $eRI_c(0)/\Delta_0$ on the normalized dielectric gap Σ/Δ_0 (charge or an electron, R - resistance of junction, Δ_0 - superconductor energy gap in absence of dielectric gap) for various values of v ranging from 0.1 to 10. The parameter was found to decrease much slower with increasing width of the dielectric gap as the parameter v characterizing the density of electronic states increases and to drop to zero at some lower value of Σ/Δ_0 as v decreases below 1. Figures 4; references 13.

UDC 537.312.62

Photocurrent in Tunnel Junction Between High-Tc Superconductor and Degenerate Semiconductor

[Article by V.N. Alfeyev and L.N. Neustroyev]

[Abstract] The possibility of a photocurrent being generated in a tunnel junction between a high-T_c superconductor such as $YBa_2Cu_3O_7$ and a degenerate semiconductor such as Sm is considered, a prerequisite being that the superconductor have a wide energy gap. This superconductor material with a critical temperature T_c about 92 K has a Cooper pairing energy at zero temperature $2\Delta_0$ within the 30-60 meV range, comparable with the energy of infrared photons. Superconductors of this class are therefore suitable for use in infrared detectors, among them, those which operate by measuring the quasiparticle flux which flows through a tunnel junction upon annihilation of Cooper pairs by the incident radiation. Such a device is examined, taking into account the effect of thermal background radiation which raises the ambient temperature far above the superconductor temperature. Analysis of the problem is based on the phonon mechanism of high-temperature superconductivity, namely on the corresponding coupled two equations of electron concentrations and phonon concentration kinetics. The quantum yield is calculated accordingly, whereupon the performance characteristics of such an S-Sm junction are compared with those of a Si:B photoresistor and found to be better at low levels of background radiation. Article was presented by Academician A.M. Prokhorov on 18 June 1989. Figures 2; references 12.

New Exact Solution to Einstein's Equations for Gravitational Field of Stationary Axisymmetric Mass

[Article by V.S. Manko and Sh.A. Khakimov, 'Friendship of Nations' University imeni Patrice Lumumba]

[Abstract] An axisymmetric exact solution to Einstein's field equations is obtained which generalizes the Gutsunayev-Manko solution (1989) and also covers the Kerr

metric as a special case. This new solution contains the quadrupole moment Q as an additional parameter so that the source of the gravitational field can be an arbitrary one dependent neither on the mass M nor on the angular momentum J. The solution is obtained by the method of nonlinear superposition in terms of Ernst's complex potential $\varepsilon = (R_+ + R_- - 2k A_-)/(R_+ + R_- + 2k A_+)$ with $A_{+/-}$ expressed in canonical Weil-Papapetrou coordinates ρ, z and real constants α, k, l. Another special case besides the Kerr metric with $l = 1$ and the Gutsunayev-Manko solution with $l = -1$ is the Schwarzschild metric with $\alpha = 0$ for a nonrotating black hole and a total mass $M_0 = k$. References 11.

UDC 537.312.62

Change in Characteristics of Superconducting Transition in Y-Ba-Cu-O System Under Mechanical Load

[Article by T.S. Orlova, B.I. Smirnov, V.V. Shpeyzman, Yu.P. Stepanov, and S.P. Chernova, Institute of Engineering Physics imeni A.F. Ioffe, USSR Academy of Sciences, Leningrad]

[Abstract] An experimental study of superconducting transition in $YBa_2Cu_3O_{7-d}$ ceramic was made concerning the effect of uniaxial compression on the critical temperature and the critical current, and also on the current-voltage characteristic. Specimens of the ceramic were produced by mixing Y_2O_3, CuO, and $BaCO_3$ powders in amounts ensuring a Y:Ba:Cu = 1:2:3 ratio, grating the mixture and then molding it by compaction into 4 mm thick 8x8 mm^2 square plates. These were annealed in an oxygen atmosphere, with not only the temperature and the length of time, but also the rate of subsequent cooling varied as did the superconducting transition characteristics. While the critical temperature for all specimens was consistently within the 93-90 K range, their critical current varied widely over the 1 - 120 A/cm_2 wide range. One lot of specimens was produced with the structure intentionally distorted to various degrees by addition of silver in various amounts. This was achieved by regrating the plates and adding $AgNO_3$ powder in various amounts up to 25 wt.% Ag, then remolding the mixture by compaction into square bars ranging in size from 4 mm long and 2x2 mm^2 to 10 mm long and 4x4 mm^2. These were annealed in an oxygen atmosphere twice at 930°C for 6 h, the second time after they had been ground to powder and the powder remolded. The mechanical load applied to all specimens was varied up to a maximum corresponding to axial compression by a pressure of 100 MPa or an approximately 0.33 kbar hydrostatic component of the stress tensor. The mechanical load was found to slightly raise the critical superconducting transition temperature and the critical current, the temperature dependence of the electrical resistivity, measured from 110 K down,

changing to one with a slightly faster decrease of electrical resistivity before transition and its slightly slower decrease through the transition range. The current-voltage characteristic was measured under no load, under uniaxial compression with the current passing either in the direction of the load or in a transverse direction, and after removal of the load. The characteristic was found to shift toward higher current, the magnitude of the shift depending on the magnitude of active or residual strain and on the direction of strain relative to the direction of current flow. The addition of silver to $YBa_2Cu_3O_{7-d}$ ceramic was found to shift the critical temperature under load upward typically from 90.7 K without Ag to 93 K with 4.2 wt.% Ag and then downward with further increasing Ag content. Addition of silver was found to lower the critical current under load typically from 120 A/cm^2 without Ag to 34 A/cm^2 with 2.9 wt.% Ag, to lower it slightly further before raising it slightly and then again to lower it monotonically toward zero with the Ag content increasing toward 25 wt.%. Addition of silver was found to decrease the shift of the current-voltage characteristic under load, about 1.25 wt.% Ag fully compensating a $\Delta j = 45$ A/cm^2 shift of the 0.5 mV voltage point (critical current 120 A/cm^2 without Ag). Figures 5; tables 1; references 16.

Observing Penetration of Abrikosov Vortices Into Superconducting Nb Films With Aid of Josephson Tunnel Junction

[Article by V.N. Gubankov, M.P. Lisitskiy, and I.L. Serpuchenko, Institute of Radio Engineering and Electronics, USSR Academy of Sciences, F.N. Sklokin, Moscow Institute of Steel and Alloys]

[Abstract] An experimental study of Abrikosov vortices in superconducting Nb films was made, two such films serving as electrodes separated by an AlO_x substrate in an SIS-sandwich with a Josephson tunnel junction. The upper Nb film was about 400 nm thick and the lower Nb film was about 200 nm thick, the weak-link region covering a 12 μm square area. Both Nb films were characterized by a London length $\lambda(4.2K) = 85$ nm approximately, and a coherence length $\xi(4.2K) = 13$ nm approximately. While the structure was held at a constant temperature below the critical superconducting transition temperature T_c, an external magnetic field normal to the plane of the tunnel junction was applied gradually from zero intensity up, and then removed after the normal component of magnetic induction B_n had reached a certain level. The critical Josephson current was then measured so that its dependence on the parallel component B_p of magnetic induction could be determined. From zero up to a certain magnitude of the normal component B_n^* the dependence of the critical current on the parallel component was found to follow the Fraunhofer "vortex-free" curve, but at B_n^* (approximately 10 G at 4.2 K), the trend of this dependence

changed with a jump followed by a lower maximum critical current and a higher first minimum critical current. This was an indication of Abrikosov vortices first having appeared in the junction region and then being captured by pinning centers, as the normal component of magnetic induction had reached that critical level. The pattern was found to be analogous with the polarity of the external magnetic field reversed, but the critical magnitude of the normal component B_n^{-*} to be lower (approximately 6 G at 4.2 K). The separately plotted dependence of the critical Josephson current on the normal component of magnetic induction confirmed the penetration of Abrikosov vortices at B_n^* and their departure from the junction region at B_n^{-*}, this dependence being characterized by a hysteresis of the vortex penetration and pinning process. As the temperature was raised above 4.2 K, the hysteresis loop became narrower with B_n^{-*} first approaching B_n^* in magnitude only, then at approximately $0.75T_c$ also changing its sign to that of B_n^*, and at $0.89T_c$ becoming equal to B_n^* in magnitude as well as sign so that the hysteresis loop completely vanished. The authors thank M.Yu. Kupriyanov for discussing the results. Figures 3; references 7.

UDC 532.132

Second Sound in Superfluid He-3 in He-4 Solutions

[Article by I.N. Adamenko, K.E. Nemchenko, and V.I. Tsyganok, Kharkov State University imeni A.M. Gorkiy]

[Abstract] A treatise on the theory of second sound in superfluid solutions is presented with coverage of a wide frequency range including both hydrodynamic and kinetic modes as well as a wide temperature range within which all quasiparticles (phonons, rotons, impurons) play a role. The dispersion equation for second sound representing collective vibrations in a quasiparticle gas is derived from the system three equations of kinetics in the zeroth approximation, disregarding the density of the normal component ρ_n as a negligible fraction of the total density $\rho_{He-4} + \rho_{He-3}$ of the solution, but including thermal excitations and their appreciable role. The hydrodynamic approximation is considered for low-frequency second sound and the kinetic approximation is considered for high-frequency second sound, relative to frequency of first sound. For low-frequency second sound in superfluid pure He-4 as well as He-4 with 0.5% and 1% He-3 is calculated the temperature dependence, over the 1.2-2.0 K range, of the attenuation coefficient and its four components representing sound absorption due to heat conduction, first and second viscous damping, and diffusion respectively. In the kinetic approximation high-frequency second sound is found to propagate through the roton-impuron system, the phonon part of attenuation is not frequency dependent.

The intermediate range is characterized by either spatial or frequency dispersion depending on the phonon relaxation time and by an attenuation coefficient which reaches its maximum when the frequency of second sound becomes comparable with the frequency of collisions leading to full equilibrium in the phonon system. The temperature dependence of the attenuation coefficient within this frequency range of second sound, calculations covering the 0-1.0 K range, indicates that the coefficient becomes maximum at a temperature within 0.3-0.5 K, both its maximum value and the temperature depending on the He-3 concentration as well as on the sound frequency. Figures 4; references 18.

UDC 538.945

Possible Realization of High-Temperature Superconductivity in Semiconductors

[Article by Yu.A. Bumay, I.G. Gorolchuk, D.S. Domanevskiy, A.V. Stepanenko, A.B. Timofeyev, A.G. Ulyashin, N.V. Shlopak, S.A. Shilo, and I.A. Yurchenko, Belorussian Polytechnic Institute, Minsk]

[Abstract] The possibility of "semiconductor" superconductivity, in the absence of free charge carriers, is analyzed from the standpoint of Bose condensation with delocalization of bound electron or hole pairs. By laser-annealing semiconductor layers after ion implantation of impurity elements which produce two-charge impurity levels, it is possible to attain impurity concentrations far above the solubility limit sufficient for dislodging electron or hole pairs whose radii are small. The effective mass of a boson carrying a charge 2e will depend on the delocalization mechanism, one of them directly overlapping the pairs' wave functions so that a band of two-electron states appears and another one being "hybridization" of bound states with states in the empty conduction band. Theoretical calculations based on the width Δ of delocalized states and supported by numerical estimates yield a critical superconducting temperature of about 100 K for Si:S and Si:Se materials with an electron concentration $n = 10^{21}$ cm^3 and an effective boson mass $M_b = 10m_e$ (m_e - mass of an electron). The feasibility of attaining such high T_c temperatures is indicated by experimental data on Si:Se and SiC:Se materials with various Se$^+$ concentrations annealed by laser pulses of 3-7 J/cm^2 energy density. The temperature dependence of magnetic susceptibility, measured with a 1 MHz alternating current down to 20 K, indicates that there is a limiting Se$^+$ concentration for appearance of an anomaly in this dependence and thus for a formation of two-electron states. The temperature dependence of electrical resistivity, measured up to 4.2, reveals its rise at about this temperature without anomalies, the rise being characteristic of the jump mechanism and indicating an open sublattice of superconduction paths. Figures 1; references 32.

UDC 538.945

Effect of Electromagnetic Radiation on Transient Characteristics of Superconducting Channels

907J0108C Kiev FIZIKA NIZKIKH TEMPERATUR in Russian Vol 16 No 6, Jun 90 pp 784-787

[Article by G.Ye. Churilov, D.A. Dikin, V.M. Dmitriyev, and V.N. Svetlov, Institute of Low-Temperature Engineering Physics, UkSSR Academy of Sciences, Kharkov]

[Abstract] An experimental study was made concerning non-Josephson current oscillations in narrow Pb-film channels exposed to an external electromagnetic field, its frequency being varied over the 10^6 - 10^{10} Hz range and its amplitude being varied over a wide range. Measurements of the reflected signal have yielded the frequency dependence of its amplitude and on the transport (direct) current. This dependence was found to be monotonic over the 10^6-10^8 Hz range as long as the transport current was either smaller or larger than the oscillation current, indicating a film impedance without anomalies within this frequency range. With the direct current equal or close to the oscillation current, synchronous detection at a frequency close to that of the oscillation current revealed an anomaly of the resonance kind in the frequency dependence of the reflected signal: its amplitude dipped below and peaked above the oscillation current frequency as "crossover" or center frequency of the 1 MHz wide range from maximum amplitude to minimum amplitude, this anomaly indicating a film in the resistive state and evidently not being associated with relaxation oscillations. Subsequent measurements yielded the dependence of the critical current and the non-Josephson oscillation frequency on both frequency and power of the incident signal, at temperatures within the range corresponding to a positive slope of the frequency-current characteristic. Measurements were made, first with the frequency of incident radiation corresponding either to superconductivity stimulation or to superconductivity inhibition, both frequencies above that resonance range. As the power of that incident radiation was increased, the non-Josephson oscillation current frequency was found to either also increase in the superconductivity stimulation mode or to decrease in the superconductivity inhibition mode while the critical current followed the opposite trend in each case. At low incident microwave power in the superconductivity stimulation mode, moreover, its derivative with respect to that power corresponded to the Aslamazov-Larkin effect in films with a weak link and with a phase slip center in superconducting channels. Measurements were then made with the frequency of incident radiation

power within or below that resonance range. The critical current became in each case lower as the incident radiation power was increased, indicating superconductivity inhibition, while the non-Josephson oscillation current frequency remained constant in the first case and decreased in the second case. The results reveal a paramagnetic nature of superconducting Pb films. Figures 3; references 8.

Isotope Effect in Model of Superconductor With Structural Phase Transition

907J0116A Moscow TEORETICHESKAYA I MATEMATICHESKAYA FIZIKA in Russian Vol 84 No 1, Jul 90 pp 120-127

[Article by N.M. Plakida, Joint Institute of Nuclear Research, and A.Yu. Chernyy, Moscow State University imeni M.V. Lomonosov]

[Abstract] A relation between the isotope effect in high-T_c superconductors of the $La_{2-x}(Ba,Sr_xCuO_4)$ group and structural phase transition in their lattice is established on the basis of the electron-phonon mechanism, this effect being shown to be substantially altered by soft optical phonon modes. While the critical superconducting transition temperature T_c for monoatomic metal superconductors is proportional to $M^{-\alpha}$ (M - atomic weight of superconductor element) and $\alpha \approx \frac{1}{2}$ for transition metals, for polyatomic superconductor compound $\alpha_i = -\delta(logT_c)/ \delta(logM_i)$ for each constituent element i and for those metal-oxide superconductors the effective α depends on the impurity metal concentration x. From the Hamiltonian of the electron-phonon subsystem of those superconductors is obtained a self-consistent equation for Green's electron temperature functions which yields the electron-phonon interaction constant and thus the critical temperature. For the electron-phonon model describing a superconductor with structural phase transition, this Hamiltonian is rewritten in terms of the normal local coordinates and momenta of soft phonon modes in primitive lattice cells. Following a change to phonon variables, Green's delay function is calculated with the aid of the corresponding system of Heisenberg equations for an asymptotically exact solution to the given boundary-value problem. The isotope effect is then calculated from the electron-phonon interaction constant in the Debye approximation. The dependence of critical temperature T_c, the critical structural phase transition temperature T_d, and α is established and evaluated on this basis for that group of metal-oxide superconductors. Numerical calculations confirm that T_c is highest when equal to T_d, while α is then minimum. Figures 2; references 19.

UDC 538.945

T_c and Rhombic Distortions in Hubbard's High-T_c Superconductor Model

[Article by V. A. Ivanov, M. Ye. Zhuravlev, General and Inorganic Chemistry Institute at the USSR Academy of Sciences imeni N. S. Kurnakov, Moscow]

[Abstract] In early high-T_c superconductor (VTSP) studies, undue attention has been given to the tetragonal-to-rhombic structural phase transition. This transition's minor role in attaining high-T_c became evident with the discovery of VTSP in Bi- and Tl-based cuprates which may also be tetragonal. The effect of rhombic distortions of a square a-b lattice on T_c was examined in the framework of the kinematic superconductivity model. A classic Hubbard model of a two-dimensional lattice with infinite intra-atomic repulsion of orbitally nondegenerate 3d-electrons was selected as the VTSP model. The effect of rhombic distortions of the CuO_2 layer on T_c was examined. It is shown that at realistic rhombic deformations of the crystal lattice, T_c may increase by tens of percentage points; this is generally consistent with experimental data for $YBa_2Cu_3O_{7-y}$, $La_{2-x}Ba_xCuO_{4-y}$, and $La_{2-x}Sr_xCuO_{4-y}$. The authors are grateful to V. I. Simonov for data on the $T_c(x)$ concentration dependence for $La_{2-x}Sr_xCuO_{4-y}$ single crystals. The study was sponsored by the VTSP Scientific Council and was carried out pursuant to Project No. 342 of the State "VTSP" Program. References 20: 6 Russian, 14 Western; figures 1.

UDC 538.945

Impulse Studies of Resistive Phase in Bulk $Ti_{1-x}V_x$ Superconductors; Metastable Current States

[Article by A. F. Perekul, A. B. Rolshchikov, N. I. Shchegolikhina, S. V. Yartsev, Metal Physics Institute at the Urals Branch of the USSR Academy of Sciences, Sverdlovsk]

[Abstract] Ti-V alloys with a 18.5 - 20 percent vanadium content obtained by electric arc smelting in a purified argon medium and by quenching ingots on a water-cooled copper base were studied. Ingots were cut by the electrospark method into 0.9x0.9x11 mm^3 bars and I-V characteristic was recorded. The bars were placed in liquid helium and their temperature was controlled within 4.2-1.9K by evacuating the vapors. The use of a diaphragm manostat made it possible to maintain the temperature with a 10^{-3}K accuracy while measuring it by the vapor pressure. The effect of two types of current pulses on resistance in a bulk superconductor in a resistive phase was examined. The resulting experimental data convincingly show the existence of metastable current-flow states; their evolution with temperature demonstrates that these states are the same in all cases and are determined by the sample structure rather than the thermal balance conditions. At a given temperature, resistance is not a unique function of current and there is a set of discrete values. References 6; figures 5.

Unambiguity of Predictions Based on General Theory of Relativity

[Article by Jose A. Ferrari, Institute of Theoretical Physics, Berlin Technical University]

[Abstract] The author proves that predictions based on the general theory of relativity are unambiguous and thus disagrees with A.A. Logunov and Yu.M. Loskutov by indicating an error in their proof (TEORET-ICHESKAYA I MATEMATICHESKAYA FIZIKA Vol 76 No, 1988), based on solution of two Einstein equations for ds_a^2 and ds_b^2 respectively, that predictions of this theory are ambiguous. The error, according to Ferrari, lies in assuming that the coordinates r, θ, φ for these equations coincide with coordinates r, θ, φ which may be regarded as spherical ones at infinity in space. The error is demonstrated by letting one experimenter on Mercury measure the proper time interval from departure to arrival of a light signal traveling around the sun and then calculate $\Delta s_a = 2\pi r_p$ while letting another experimenter on Mercury measure that time interval with the same clocks and then calculate $\Delta s_b = 2\pi r_p (1 + GM/r_p)$ calculation of each experimenter being based on the metric of the corresponding Einstein equation. Then obviously $\Delta s_a = \Delta s_b$ and thus r_p is not equal to r_p so that the two Logunov-Loskutov equations (27),(28) are either not valid when the same value for the quantity "a" appears in both or are valid when the correspondingly different values of "a" appear in them. This does not prove that the prediction is ambiguous, however, inasmuch as in fact the same symbol "a" has been "accidentally" used in the two Logunov-Loskutov equations (29),(30) even though the corresponding value is different in each. References 1.

UDC 517.956

Solvability of Boundary-Value Problems for Certain Systems of Differential Equations

[Article by V.A. Malovichko, Kiev Food Industry Institute of Technology]

[Abstract] Four boundary-value problems are considered for the system of differential equations which describe propagation of perturbations through a viscous medium occupying a cylindrical region $\Omega = G \times (0,T)$ (G - bounded region in R_n space with piecewise-continuous boundary δG, $T > 0$), all coefficients in this system being symmetric matrices. The solutions to the first two problems are to satisfy on the boundary $\delta G \times (0,T)$ the condition of zero displacement at time $t = 0$ and the condition of zero velocity at time $t = T$ respectively. Following a direct verification with the aid of three lemmas (the second of them using the generalized Cauchy-Schwarz inequality) that the two boundary-value problems are coupled, a strong solution is defined in terms of an infinite series converging to a zero limit. A theorem is then stated pertaining to conditions for existence and uniqueness of a strong solution to each of these two problems. The solutions to the other two problems are to satisfy on surface $S = \delta G \times (t_1, t_2)$ the condition of zero displacement at any time $t_1 < 0$ and zero velocity at any time $t_2 > 0$ respectively. These two problems, with the aid of analogous three lemmas, are shown also to be coupled. Following an analogous definition of a strong solution, an analogous existence and uniqueness theorem is then stated for such a solution to each of them. References 4.

Groups With Minimax Factor-Groups

[Article by L.A. Kudrachenko and V.V. Pylayev, Kiev Polytechnic Institute]

[Abstract] Groups whose every normal nonminimax subgroup determines a minimax factor-group are examined, a minimax group containing a finite subnormal series whose factors satisfy the condition of minimality or maximality for the subgroup. Such a group G thus contains either an increasing series of normal subgroups with minimax factors or includes a normal minimax subgroup H such that G/H contains no nonunitary normal minimax subgroups, only the first kind of groups being considered here, and particularly the class of such groups which contain an increasing series of normal subgroups with either finite or Abelian minimax groups as factors. A theorem is proved, with the aid of two lemmas, which states the condition for such a group including a finite normal subgroup F such that $G/F = G \leq G_1 \times G_2$. Here G_1 denotes a minimax group, G_2 denotes a group which includes a normal infinite elementary Abelian p-subgroup $A \leq FC(G)_2$ infinitely irreducible into G_2, and $FC(G)$ denotes the characteristic subgroup of group G also called its center. A corollary is subsequently proved stating the condition inclusion of a hypercentral normal subgroup $H \geq A$ in a G_2 group. References 12.

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