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13 March 1981

... FBIS 40TH YEAR 1941-81 ...

USSR Report

PHYSICS AND MATHEMATICS

(FOUO 2/81)

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On behalf of all of us in FBIS I wish to express appreciation to our readers who have guided our efforts throughout the years.

JPRS L/9604

13 March 1981

USSR REPORT

PHYSICS AND MATHEMATICS

(FOUO 2/81)

CONTENTS

FLUID DYNAMICS

UDC 532.135:532.5:536.242:532.584

RHEODYNAMICS AND HEAT AND MASS EXCHANGE

Novosibirsk REODINAMIKA I TEPLOMASSOOBMEN in Russian 1979 signed to press 19 Jul 79 pp 4, 153-155

[Annotation and abstracts from collection "Rheodynamics and Heat and Mass Exchange" edited by Academician Samson Semenovich Kutateladze and Doctor of Technical Sciences Yevgeniya Moiseyevna Khabakhpasheva, Siberian Department, Institute of Thermal Physics, USSR Academy of Sciences, 400 copies, 155 pages]

[Text] The collection gives the results of theoretical and experimental research done in recent years at the Laboratory of Heat Exchange and Rheodynamics of the Institute of Thermal Physics. An examination is made of some problems of flow of rheological media with consideration of relaxation phenomena and anisotropy of normal stresses. A description is given of the results of an experimental study of rheological flows by optical methods under different conditions of deformation. A general approach is outlined for deriving macroscopic equations of transfer in dispersed media. Considerable review material is also given on heat exchange in laminar and turbulent forced convection of non-Newtonian fluids.

The materials published in the collection are of interest both to specialists in the field of non-Newtonian fluid mechanics and thermal physics, and to those who produce and process polymer materials.

UDC 532.135+536.242

CONVECTIVE HEAT EXCHANGE IN RHEOLOGICAL MEDIA

[Abstract of article by Ye. M. Khabakhpasheva]

[Text] The article is a presentation of a survey report delivered at the Fourth International Conference on Heat Exchange.

Problems of heat exchange in laminar and forced turbulent convection of rheostable non-Newtonian fluids that can be treated as homogeneous media are discussed. Under conditions of laminar flow an estimate is made of the way that heat exchange is affected by the dependence of viscosity on shear velocity, dissipation of mechanical energy and the temperature behavior of viscosity.

An examination is made of the problem of turbulent flow of non-Newtonian fluids that do not have appreciable elastic properties. An analysis is made of the causes

of reduced heat exchange when small amounts of certain high-molecular polymers are added to water. The present discrepancies between the results of calculations and experiments are discussed. Figures 26, references 86.

UDC 532.5:532.135

RHEOLOGICAL FLOWS UNDER CONDITIONS OF THE INSTANTANEOUS APPLICATION OF CONSTANT AND OSCILLATING SHEAR VELOCITY

[Abstract of article by V. I. Popov and A. N. Kekalov]

[Text] Based on the example of transitional and oscillating shear flow of a liquid an analysis is made of the properties of a previously proposed rheological equation of state and the results are compared with certain known theories and experimental data. The analysis shows that the given model describes known peculiarities of the mechanical behavior of viscoelastic liquids, and moreover reveals some peculiarities unpredicted by other theories. Figures 7, references 10.

UDC 532.135+532.517.2

SOME RESULTS OF INVESTIGATION OF RHEOLOGICAL FLOWS BY OPTICAL METHODS

[Abstract of article by Ye. M. Khabakhpasheva, V. I. Popov, I. M. Gruzdeva, E. L. Ivakina, V. M. Karsten and A. I. Bakhtiyarov]

[Text] The paper gives the results of studies of laminar flows of non-Newtonian fluids by an optical-mechanical device, methods of stroboscopic visualization, birefringence and photometry.

An investigation is made of the kinematic characteristics of flow in a channel under conditions of onset and development of an unstable flow mode. The method of stroboscopic visualization yields the fields of instantaneous and averaged velocities as well as the mean-square pulsations of velocity. A study is done on the way that these quantities depend on shear stress and the shape of the channel inlet. A laser probing method is used to get the spectral and autocorrelation functions of velocity pulsations in the unstable flow mode.

An examination is made of the particulars of flow of viscoelastic liquids in channels with cavities. A study is done on the dynamics and completeness of replacement of the liquid in a cavity by the viscoelastic separator used in cementing oil and gas wells. Figures 28, references 32.

UDC 532.584

ON DERIVATION OF MACROSCOPIC EQUATIONS OF TRANSPORT IN DISPERSED MEDIA

[Abstract of article by A. G. Grossman]

[Text] The author proposes a general approach to derivation of macroscopic equations of transport in dispersed media with consideration of the influence of effects associated with surface phenomena on the particles of the dispersed phase. The method that is used is adapted to determination of macroscopic quantities as

averages over a statistical ensemble of realizations of macroscopically indistinguishable states of a dispersed medium, and to closure of macroscopic equations by statistical methods. An examination is made of general simplifications of transport equations that can be made in the case of local homogeneity of the dispersed medium.

UDC 532.584

FLOW OF MODERATELY CONCENTRATED SUSPENSIONS IN THE STOKES APPROXIMATION

[Abstract of article by A. G. Grossman]

[Text] An examination is made of the problem of closure of macroscopic equations for slow quasi-steady flow of moderately concentrated suspensions. A closed system of macroscopic equations is derived for flow of a suspension of neutrally suspended solid spherical particles in a Newtonian fluid with consideration of pairwise hydrodynamic interactions. It is shown that under certain conditions the flow of the suspension in this case is characterized by a localized macroscopic coefficient of viscosity that coincides in form with the effective coefficient of viscosity found by J. C. Batchelor. References 6.

UDC 532.135:532.546

FLOW OF POLYMER MELTS THROUGH A GRANULAR BED

[Abstract of article by Z. Kemblovskiy and M. Dyubinskiy]

[Text] The paper gives the results of investigations of resistance to the flow of polymer melts thorugh a granular bed. It is shown that flows of melts with Debora numbers greater than 0.05 are accompanied by "memory" effects that must be taken into consideration. On the basis of research results a correlation equation is proposed for calculating the resistance to flow of polymer melts through a granular bed with shear velocities from 0.6 to 36 s^{-1}. Figures 11, table 1, references 17.

[15-6610]

6610
CSO: 1862

STABILITY OF SHOCK WAVES IN A THOMAS-FERMI GAS

Novosibirsk CHISLENNYYE METODY MEKHANIKI SPLOSHNOY SREDY in Russian Vol 4, No 5, 1973 pp 143-148

[Article by T. N. Fortova, A. N. Dremin and V. Ye. Fortov, Department of the Institute of Chemical Physics, USSR Academy of Sciences, Moscow]

[Text] At the present time, in connection with the elaboration of questions in pulsed initiation of thermonuclear reactions [Ref. 1] considerable interest has arisen in hydrodynamic phenomena at extremely high pressures ($P \lesssim 10^7$ Mbar) and temperatures $T \lesssim 10^9$ °K) that may be realized when powerful luminous [Ref. 2] or electron [Ref. 3] fluxes act on a condensed substance. Depending on the rate of energy input, shock waves of extremely high intensity may be produced in the target that are unstable with respect to spontaneous acoustic emission.

The stability of a planar steady-state discontinuity with respect to two-dimensional curvatures of the front was first considered in Ref. 4. The system of hydrodynamic equations that describe the motion behind the shock wave front was linearized relative to perturbed motion, and thanks to the steady-state nature of the main flow, an exponential time factor was isolated in the solution that defines the nature of development of perturbations in the flux. The solution of Ref. 4 was later enlarged by consideration of "entrainment" of perturbations by the flux, so that the following stability criteria were finally formulated [Ref. 5, 6]:

$$\left(\frac{dV}{dP}\right)_H < \frac{V-V_0}{P-P_0}, \qquad (1)$$

$$\left(\frac{dV}{dP}\right)_H > \frac{V_0-V}{P-P_0}\left(1+2\sigma^{-1}\frac{D}{c}\right), \qquad (2)$$

$$\frac{V_0-V}{P-P_0}\,\frac{1-\sigma^2(D/c)^2+\sigma^{-1}(D/c)^2}{1-\sigma^2(D/c)^2+2\sigma^{-1}(D/c)^2} < \left(\frac{dV}{dP}\right)_H < \frac{V_0-V}{P-P_0}\left(1+2\sigma^{-1}D/c\right), \qquad (3)$$

where V_0P_0 and VP are states preceding and following the shock discontinuity, D is velocity in the laboratory coordinate system, $\sigma = V_0/V$; $c=\sqrt{-V^2\left(\frac{dP}{dV}\right)_S}$; $\left(\frac{dV}{dP}\right)_H$ is the slope of the shock adiabat.

Inequalities (1), (2) correspond to absolute instability of the discontinuity -- an exponential increase in perturbations with elapsed time. Moreover, the increment of this rise is considerable, so that the perturbations rapidly reach the nonlinear region for which there is no solution at present. However, case (1) has been experimentally studied and corresponds to decay of the wave into two discontinuities that propagate with different velocities [Ref. 7]. Inequality (3) corresponds to a zero real part of the increment, and leads in the linear approximation to spontaneous emission of sound waves by the discontinuity toward the shock-compressed medium. A solution of higher orders is also needed in this case to clarify the actual flow pattern.

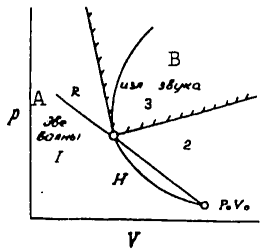

Fig. 1

A--two waves
B--sonic emission

Fig. 1 gives a geometric interpretation of stability criteria (1)-(3). A break in the shock adiabat H below the Rayleigh line $R=\frac{V_0-V}{P-P_0}=\text{const}$ leads to instability (1) and formation of a two-wave structure. A sharp bend in the shock adiabat $\left(\frac{dV}{dP}\right)_H>0$ when (2) is satisfied also corresponds to absolute instability. Criterion of sonic instability (3) is weaker than (2), and in principle does not require a change in the sign of $\left(\frac{dV}{dP}\right)_H$, although it is for shock adiabats with a bend in the PV plane that sonic instability is most probable.

According to the ideas that have now been developed, the lower boundary of the statistical description of condensed matter is on a pressure level of a few hundred megabars [Ref. 8], above which the thermodynamic properties are confidently described in the quasi-classical approximation by self-consistent field methods (the Thomas-Fermi theory). The Thomas-Fermi equations at a finite temperature were numerically solved in Ref. 9, and the following approximations [Ref. 10] have been proposed for the electronic component of pressure P_e and excitation energy E_e:

$$P_e(V,T)=\frac{4.52\,Z^{1/3}T^2(VM)^{-1/3}}{1+5.45\cdot10^{-6}Z^{-2/3}(VM)^{2/3}T}\left[1+\frac{1.35\cdot10^{-2}(ZVM)^{1/2}}{1+4.2\cdot10^{-10}Z^{-1}VMT^{3/2}}\right]^{-1},\tag{4}$$

$$E_e(V,T)=P_eV\left[1.5+\frac{3.3\cdot10^{-5}(ZVM)^{1/3}(T^{-8/3}Z^{-32/27}+3.34\cdot10^{-3})}{1+3.43\cdot10^{-4}Z^{-2}T^{-3/2}+1.02\cdot10^{-8}Z^{-10}VMT}\right]\left[1+\frac{3.78\cdot10^{-5}(ZVM)^{-0.161}\cdot Z^{4/3}T^2}{T+2.46\cdot10^{-3}Z^{4/3}(ZVM)^{-0.223}}\right],$$

The describe the data of Ref. 9 within 10%, and have true asymptotes to a degenerate electron gas and an ideal Boltzmann gas:

$$V\to0;\ T\to0;\ P_e\sim T^2V^{-1/3};\ E_e\sim T^2V^{2/3}\tag{5}$$

$$V\to\infty\ \ T\to\infty;\ P_e\sim TV^{-1/3};\ E_e\sim T.\tag{6}$$

In view of the large mass of nuclei, the nuclear components of the system were described in the ideal-gas approximation, disregarding correlation effects:

$$P_n(V,T)=\frac{R}{V}T;\quad E_n=\frac{3}{2}P_nV. \tag{7}$$

The cold components were taken in the following form [Ref. 10]:

$$P_x=Z^{10/3}/\sum_{i=0}^{5}\alpha_i(ZVM)^{(i+5)/3};\quad E_x=-\int_{V_0}^{V}Z^{10/3}/\sum_{i=0}^{5}\alpha_i(ZVM)^{(i+5)/3}. \tag{8}$$

The shock compression adiabat in the Thomas-Fermi approximation was calculated by numerical solution of the equation of dynamic compatibility:

$$E-\frac{1}{2}P(V_0-V)=0. \tag{9}$$

The total pressure P and internal energy E of the system are the sum of the components (4), (7) and (8). The asymptotic behavior of the electronic components (6) leads to limiting compression ($P\to\infty$) of matter $\sigma_\infty'=4$ in accordance with the expression for a density jump in a strong shock wave ($P\gg P_x$) [Ref. 7].

The form of the Hugoniot adiabat in the vicinity of the bend depends on the ratio between the potential energy Q and translational energy E_{tr} and is determined by the specific law of interaction compression and degeneration of the electronic component.

In the temperature region $T\gtrsim10^6$ °K, in addition to (4), (7) and (8) we must consider the contribution of pressure P_Λ and emission energy E_Λ, which in the case of local thermodynamic equilibrium are written in the form [Ref. 7]

$$P_\Lambda=\frac{4\sigma T^4}{3C}V;\quad E_\Lambda=\frac{4\sigma T^4}{C}V. \tag{10}$$

Equilibrium radiation causes a qualitative change in the pattern of shock compression, leading to a new asymptotic form for density $\sigma_\infty\to7$ as $P\to\infty$, and elimination of the inflection of the Hugoniot adiabat in the PV plane.

Correspondence between these two models of reality is verified by checking the condition of blocking of radiation in a shock-compressed medium with characteristic dimension $l\sim0.1$ cm. At $T\gtrsim10^6$ °K the main fraction of equilibrium radiation goes to the x-ray spectrum with wavelengths $l\lesssim5\cdot10^{-7}$ cm. If we take free-free electron transitions as the principal mechanism of absorption of such radiation, the mean free path of radiation of interest to us is much greater than l. At emission frequencies of the order of the plasma frequency $\omega\sim\omega_p=\sqrt{4\pi n_e l^2/m_e}$ there is a collective mechanism of absorption due to buildup of the instability in the skin layer and decay of the transverse electromagnetic wave into a plasmon and an acoustic wave, and at $\omega\sim2\omega_p$ -- due to decay into two plasmons [Ref. 11]. However, under the conditions of interest to us $\omega_m=2\pi c/\lambda_m\ll\omega_p$ and these mechanisms likewise do not block an appreciable amount of radiant energy.

Fig. 2 shows the results of calculation of the shock adiabats for tungsten with various initial porosities, where the wavy line shows the region of instability with respect to criterion (3). The upper bound of this region lies outside the limits of validity of the approximation used since spontaneous production of electron-positron pairs can take place in the system at $T>2m_ec^2/K\sim10^{10}$°K [Ref. 12].

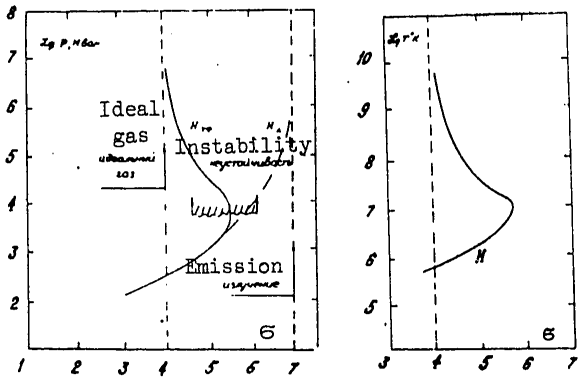

Fig. 2

In addition to tungsten, calculations have shown instability of the discontinuity for some other elements: Cu, Ni, Pb and Al. It is known that the Thomas-Fermi equations are self-similar relative to nuclear charge number Z:

$$\bar{P}=PZ^{-10/3};\ \bar{V}=VZ;\ \bar{T}=TZ^{-4/3};\ \bar{E}=EZ^{-7/3}. \quad (11)$$

In addition, transformations (11) enable elimination of Z from stability criteria (1)-(3), and from the other relations used here, (7)-(9). The specific nature of the element lies in the density of the substance under normal conditions $\rho_0 = V_0^{-1}$, which is determined by the shell structure of the atom. However, the considerable margin in satisfying criterion (3) for the investigated metals is a hopeful sign that the conclusion of shock wave instability in a Thomas-Fermi gas is universal and applies to the other elements.

The authors thank V. M. Gogolev for constructive criticism.

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11. [Not given]

12. [Not given]
[8144/0530-6610]

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CSO: 8144/0530

GEOPHYSICS

THEORY AND INTERPRETATION PROCEDURES OF GRAVITATIONAL AND MAGNETIC ANOMALIES

Moscow TEORIYA I METODIKA INTERPRETATSII GRAVITATSIONNYKH I MAGNITNYKH ANOMALIY in Russian 1979 signed to press 5 Nov 79 pp 2-4, 270

[Annotation, introduction and table of contents from collection "Theory and Interpretation Procedures of Gravitational and Magnetic Anomalies" edited by Doctor of Physical and Mathematical Sciences, Professor V. A. Kuzivanov, Institute of Physics of the Earth imeni O. Yu. Shmidt, USSR Academy of Sciences, Izdatel'stvo "Nauka", 250 copies, 270 pages]

[Text] This collection deals with the theory, methodology and numerical methods of interpreting gravitational and magnetic anomalies. New results are given on the interpretation of local two-dimensional gravitational anomalies by the method of bipolar analysis, on analytical continuation of two-dimensional magnetic anomalies, on the uniqueness of the solution of the three-dimensional potential problem, on solution of the direct problem in the method of artificial magnetization, and on systematizing methods of extracting information from data of geophysical observations.

The collection is intended for specialists in the field of exploratory gravimetry and magnetometry, instructors in colleges and universities, graduate students and upperclassmen majoring in exploratory geophysics.

Introduction

The most important stage in any geophysical research has always been, and continues to be that of processing and interpreting the data of field observations. Over the past 20 years there has been a considerable change in the makeup of this stage and in the essence of the techniques and methods used. This is due to the following circumstances:

1) there has been a sharp increase in the volume of observational data to be processed and interpreted, as well as an improvement in quality of these data;

2) there has been a sharp increase in the volume of a priori (supplementary) information on the structure of the medium that is available to the interpretor;

3) there has been an immeasurable increase in the demands on the part of geologists for precision and resolution of the geophysical interpretation and for summary materials of geophysical research used as a basis for planning geological prospecting.

In virtue of these circumstances, the stage of processing and interpretation must now be done (and indeed is being done) on computers, i. e. on the basis of strictly formalized procedures, and the procedures themselves must be optimum. All this in turn makes it necessary to go into questions of the methodology, theory and development of methods of extracting information from observational data afresh on a higher level. Although specialists in the field of interpretation have been going into these questions intensively throughout the seventies, a very great deal remains to be done.

The above-mentioned questions of the theory, methodology and construction of algorithms for extracting information are the topics of the papers in this collection. They reflect the main areas of research under development at the Laboratory of the Theory of Interpretation of Geopotential Fields of the Institute of Physics of the Earth. Let us hope that making the geophysical community aware of the results presented in these articles will serve the cause of progress in the difficult area of reconstructing the sources of physical fields from data of measurement of these fields on the surface of the earth.

Doctor of Physical
and Mathematical Sciences,
Professor V. A. Kuzivanov

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LASERS AND MASERS

UDC 621.378.33

EFFICIENT METAL-VAPOR GAS-DISCHARGE LASERS

Tomsk EFFEKTIVNYYE GAZORAZRYADNYYE LAZERY NA PARAKH METALLOV in Russian 1978 signed to press 28 Dec 78 pp 2-5, 208-209

[Annotation, preface and table of contents from collection "Efficient Metal-Vapor Gas-Discharge Lasers" edited by A. V. Lisevich, Institute of Optics of the Atmosphere, Siberian Department, USSR Academy of Sciences, 400 copies, 209 pages]

[Text] The collection presents papers by researchers at the Institute of Optics of the Atmosphere, the "Optika" Special Design Office of Scientific Instrument Making of the Siberian Department of the USSR Academy of Sciences, the Computing Center of the Siberian Department of the Academy of Sciences in Krasnoyarsk, and the Siberian Physicotechnical Institute imeni V. D. Kuznetsov on investigation of physical processes in active media, optimization, modeling and utilization of lasers in pulsed, cw and quasi-continuous operation based on transitions from resonant to metastable levels of atoms and ions.

Most of the papers are published here for the first time.

The collection may be of interest to specialists working in the field of quantum electronics and its applications.

Science editor
Candidate of Physical
and Mathematical Sciences
P. A. Bokhan

Preface

Improving the power and efficiency of lasers in both the pulsed and cw mode of operation remains one of the most important problems in quantum electronics. This problem is particularly acute for lasers of the visible and near infrared band.

One way to improve laser efficiency is to use working media in which the pumping channel for the upper working states is capable of capturing a large share of the pumping energy. For gas lasers, this occurs particularly in the case where the upper working levels are resonant states of metal atoms or ions. The investigation of such working media is covered by the materials of this collection, which gives the results of research in development of metal-vapor lasers done at the Institute

of Optics of the Atmosphere and the "Optika" Special Design Office of Scientific Instrument Making in Tomsk, and also by the Computing Center of the Siberian Department of the USSR Academy of Sciences in Krasnoyarsk in 1971-1978.

The main principles of operation of such lasers were formulated by Gould, Walter and others in the sixties. At that time their research did not attract wide attention of scientists. The situation changed considerably in 1971 when the frequency self-heating mode of copper laser operation was realized at the Physics Institute of the USSR Academy of Sciences under the direction of G. G. Petrash. This enabled an appreciable increase in the average power level of the laser with retention of the efficiency level of about 1%. An analogous working mode has now been realized for most metal atoms that have a similar level structure. Progress in the technology of making tubes and improvement of the supply systems have now led to the development of high-power sealed devices that have a unique combination of properties. In addition, some active media have been converted to continuous or quasi-continuous operation. Such a working mode has been observed in mixtures of vapors of europium with helium, strontium with helium and calcium with hydrogen.

However, despite obvious advances, there are still unsolved problems, including: 1) persistently low efficiency, far from what had previously been expected; 2) slow pace of increase in average lasing powers; 3) small number of working media that have been converted to continuous and quasicontinuous operation, and also comparatively low parameters.

Apparently the principal reason for such a state of affairs is inadequate study of the physical processes that determine lasing parameters. Therefore in most experimental research that deals with such an area as pulsed lasers with resonant upper working levels there is practically no discussion of the factors that limit efficiency, energy output, recurrence rate and average lasing power.

In the proposed collection, most of the papers deal with these problems, which has made it possible to explain the origins of the major limitations. On the one hand this has already been instrumental in the attainment of fairly high lasing parameters (e. g. copper-vapor laser efficiency has been brought to about 3%); on the other hand, the outlook for further progress in this field of quantum electronics has been clarified.

A considerable number of articles in the collection deal with lasers that have been converted to continuous or quasicontinuous emission. Since there has been rather little success in this field as yet, emphasis has been placed on more detailed investigation of the lasing mechanism of known active media rather than on the search for new media.

The value of results of any research depends considerably on the feasibility of utilization in the national economy. Therefore some attention has also been given to problems of the development of high-temperature technology, the manufacture of sealed devices and investigation of their characteristics, and also to optimization problems.

In addition to the papers that give new results, the collection also includes materials of research that has been published partially heretofore in periodicals. On the one hand, this relieves research and development people who are new to these

problems of having to look up the required papers; on the other hand, a reading of the material in its entirety undoubtedly facilitates understanding.

It should be mentioned that the development of metal-vapor lasers at the Institute of Optics of the Atmosphere and the "Optika" Special Design Office is being done mainly to produce new sources for laser probing of the atmosphere. By now a number of experiments have been done in this field that convincingly show the appreciable advantages of metal-vapor lasers, and especially copper-vapor lasers, over other types. An analogous situation may be the case as well in other areas of practical application such as laser projection microscopes, communications and navigation, hybrid optoelectronic systems for recording, storing and processing data, for pumping dye lasers and F-center lasers and so on, where the unique combination of parameters in these lasers can be put to use in full measure.

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UDC 621

ABSTRACTS OF PAPERS IN THE COLLECTION 'QUANTUM ELECTRONICS'

Leningrad KVANTOVAYA ELEKTRONIKA, TRUDY LENINGRADSKOGO POLITEKHNICHESKOGO INSTITUTA in Russian No 366, 1979 signed to press 27 Dec 79 pp 1, 114-119

[Text] This collection contains the results of research done by scientists of the radio physics department at [Leningrad] Polytechnical Institute imeni M. I. Kalinin. Considerable attention is given to questions of using lasers and masers, optical data processing and holography.

The materials of the collection cover a wide range of theoretical and experimental work in the field of quantum electronics. Physical phenomena are considered in gas lasers and neodymium-doped yttrium-aluminum garnet solid-state lasers, methods of mode selection in linear and ring lasers, the theory and application of acousto-optical devices in optical data processing systems, the use of holography in experimental techniques. Some articles deal with the development of hybrid optical-digital signal processing systems based on charge-coupled devices and computers of the "Elektronika-100" type, and also the development of devices based on nuclear magnetic resonance and quantum frequency standards.

The collection is intended for a wide range of physicists and engineers working in the field of quantum electronics and related areas, and also for upperclassmen and graduate students.

The collection has been approved by the Leading Council on Radio Physics of the Ministry of Higher and Intermediate Education of the Russian Federation.

Recommended for publication by the academic council of the radio physics department of Leningrad Polytechnical Institute imeni M. I. Kalinin.

UDC 621.373.826

A SINGLE-FREQUENCY HIGH-POWER Nd:YAG LASER

[Abstract of paper by G. F. Zaytsev, S. V. Kruzhalov and L. N. Pakhomov]

[Text] The authors give the results of a theoretical and experimental study of a single-frequency Nd:YAG laser optimized with respect to output power. The output power attained in the stable single-frequency mode was 800 mW. Figures 3, references 4.

UDC 621.373.826

A SOLID-STATE RING LASER WITH LONGITUDINAL MODE LOCKING

[Abstract of paper by A. V. Astakhov, S. L. Galkin and V. M. Nikolayev]

[Text] The paper gives the results of an experimental study of an yttrium-aluminum garnet ring laser with longitudinal mode locking. A nonreciprocal phase-shifting element based on the Faraday effect was used to produce beating of opposed waves. Measurement of the lock-in band of opposed waves gave a value of about 200-300 Hz. This low figure can be attributed to spatial separation of opposed waves under phase-locked multimode conditions. Figures 3, references 4.

UDC 621.373.826

BEAT FREQUENCY OF OPPOSED WAVES OF A MULTIMODE GAS LASER UNDER LONGITUDINAL MODE LOCKING CONDITIONS

[Abstract of paper by S. L. Galkin, B. V. L'vov, V. M. Nikolayev and K. B. Samusev]

[Text] A method of successive approximations is proposed for calculating the characteristics of gas ring lasers. On the basis of this method, the beat frequency of opposed waves in a helium-neon ring laser is calculated as a function of small changes in the length of the resonator under conditions of self-locking and induced locking of longitudinal modes. It is established that induced locking of longitudinal modes reduces the dependence of beat frequency on cavity length as compared with self-locking. The theoretical results are experimentally verified. Figures 2, references 4.

UDC 621.373.826:535.417

A MATRIX METHOD OF CALCULATING SPHERICAL RESONATORS WITH CROSS SECTIONALLY NONUNIFORM POLARIZATION ANISOTROPY

[Abstract of paper by V. Yu. Petrun'kin and N. M. Kozhevnikov]

[Text] A matrix method is proposed for analyzing optical cavities with cross sectionally inhomogeneous polarization anisotropy that generalizes the Jones method and the matrix method of calculating isotropic spherical resonators. A confocal cavity with weak axisymmetric anisotropy is calculated by using this method. Figures 4, references 6.

UDC 621.373.826

MODE INTERACTION IN A WEAKLY ANISOTROPIC GAS LASER

[Abstract of a paper by B. V. L'vov and A.L. Mel'tsin]

[Text] An analysis is made of mode interaction in a weakly anisotropic two-mode helium-neon laser with wavelength of 0.63 μm in a realistic range of pressures, intermode spacings, and differences between cavity Q's for orthogonal polarizations. An investigation is made of the width of the zone of competition between modes of

stimulated emission and the correction to the frequency of intermode beats as a function of the frequency mismatch of stimulated emission relative to the center of the line of an equal-isotope mixture in the working range of pressures at different intermode intervals. Figures 3, references 12.

UDC 621.373.826

FREQUENCY SPLITTING OF STIMULATED EMISSION OF OPPOSED WAVES IN A HELIUM-NEON GAS LASER

[Paper by R. I. Okunev and A. L. Stepanyants]

[Text] The paper gives the results of an experimental study of supplementary splitting of the frequencies of opposed waves when a beam is irised down in the cavity of a ring laser and the active element is misaligned. It is established that frequency splitting of opposed waves is caused by deviation of the capillary of the laser tube away from the axis of the cavity. Figures 3, references 6.

UDC 621.373.826

PHASE RELATIONS BETWEEN MODES IN LINEAR GAS LASERS WITH TYPE II SELF-MODE LOCKING

[Paper by O. I. Kotov and V. M. Nikolayev]

[Text] On the basis of a spectral-temporal model an examination is made of the distribution of phases in multimode laser operation. A relation is established between steady-state phases of longitudinal modes and the characteristics of the optical spectrum and of the emission pulses. The results of calculation agreee with experimental data on a linear helium-neon laser. Figures 4, references 7.

UDC 621.373.826

SOME PARTICULARS OF OPERATION OF A HELIUM-CADMIUM ELECTROPHORETIC LASER

[Paper by Ye. Yu. Andreyeva, V. V. Yelagin, D. K. Terekhin, deceased, A. E. Fotiadi and S. A. Fridrikhov]

[Text] It is established by simultaneous measurement of the power of stimulated emission and the parameters of the discharge plasma of an electrophoretic He-Cd laser that the cadmium vapor pressure in the working part of the tube does not remain constant with changing discharge current even though the temperature of the source of cadmium vapor is maintained constant within ±5°C. Application of an axial magnetic field to the active medium in the single-frequency lasing mode leads to an increase in lasing power. Figures 3, references 9.

UDC 621.373.826

INVESTIGATION OF PECULIARITIES OF COMPETITION OF OPPOSED WAVES IN A RING LASER ON THE 3.39 μm LINE

[Paper by Ye. Yu. Andreyeva, M. Yu. Kirina and D. K. Terekhin, deceased]

[Text] An experimental study is done on the effect that pressure of the gas mixture and an external axial magnetic field have on conditions of competition of

opposed waves. It is established that a reduction of pressure when consideration is taken of coupling through scattering narrows the region of competition of opposed waves. The results enable calculation of the coefficient of coupling through scattering between opposed waves, and they can be used in selecting modes of operation of laser gyroscopes. Figure 1.

UDC 621.373.826

COMBINED LASER DISCHARGE WITH MICROWAVE PREIONIZATION

[Paper by A. P. Golovatskiy, V. A. Kruzhalov, T. M. Perchanok, D. K. Terekhin and S. A. Fridrikhov]

[Text] It is proposed that a microwave discharge be used to preionize the medium of a CO_2 laser. The microwave discharge is excited in a slot cut in the narrow wall of a waveguide. Pulsed voltage is applied across an electrode opposite this slot. An investigation is made of the gain of the active medium on a wavelength of 10.6 μm as a function of pump parameters. It is established that the microwave discharge produces inversion in the medium only in the immediate vicinity of the slot, but promotes development of discharge in the main volume. High gain that is uniform with respect to volume can be achieved by appropriate selection of the pump parameters. Figures 2, references 5.

UDC 535.853

AN ACOUSTO-OPTICAL SPECTROGRAPH FOR RADIOASTRONOMICAL STUDIES

[Paper by N. A. Yesepkina, B. A. Kotov, A. V. Mikhaylov, V. Yu. Petrun'kin, S. V. Pruss-Zhukovskiy, N. F. Ryzhkov and A. I. Shishkin]

[Text] The authors examine the working principle and give the results of experimental studies of the prototype of a radioastronomical spectrograph based on an acousto-optical spectrum analyzer, a line of CCDs (charge-coupled devices) and an Elektronika-100 computer. The parameters (frequency band, resolution and radiometric gain) of such a spectrograph are determined during operation in the modulation mode. Figures 3, references 13.

UDC 621.385.832.5

CONVERTERS BASED ON CHARGE-TRANSFER DEVICES FOR CHANGING OPTICAL INFORMATION TO ELECTRICAL

[Paper by S. S. Karinskiy, B. A. Kotov and Yu. A. Kotov]

[Text] The paper outlines the principles of operation of new semiconductor charge-transfer devices. It is shown that this class of new photoelectric transducers has a combination of characteristics that enable optimum realization of the capabilities of optical computer systems and development of hybrid optical-digital data processing systems with flexible structure and extensive capabilities. Limiting values are given of the noises, errors and speed of these devices, and the major characteristics of charge-transfer devices are compared with those of other analogous devices (vidicons, dissector tubes and the like). Figures 3, references 7.

UDC 621.327.8

A DEVICE FOR COUPLING OPTICAL AND DIGITAL DATA PROCESSING SYSTEMS USING LINEAR AND MATRIX CHARGE-TRANSFER DEVICES

[Paper by Yu. A. Kotov, A. V. Mikhaylov and A. P. Novitskiy]

[Text] An examination is made of the principles of constructing an interface for programmed control of linear and matrix charge-transfer devices with data input to an Elektronika-100 computer. Estimates are made of the time of data input with a variety of interface structures using regular peripheral equipment. Figures 2, references 5.

UDC 535.241.13:534

MULTICHANNEL HIGH-FREQUENCY ACOUSTO-OPTICAL MODULATORS

[Paper by Ye. T. Aksenov, N. A. Bukharin, S. A. Rogov and I. I. Sayenko]

[Text] The authors consider questions of developing multichannel solid-state acousto-optical modulators for frequencies of 100-300 MHz. A description is given of modulator manufacturing technology and the technique for matching channel input impedances. Results of an experimental study of multichannel acousto-optical modulators are given. Figures 4, references 13.

UDC 535.241.13:534

INVESTIGATION OF ACOUSTO-OPTICAL RADIO SIGNAL SPECTRUM ANALYZERS BASED ON BRAGG MANY-PHONON SCATTERING OF LIGHT

[Paper by N. A. Yesepkina, A. A. Lipovskiy, V. V. Chkalova and A. S. Shcherbakov]

[Text] An investigation is made of the feasibility of increasing the resolution of an acousto-optical radio signal spectrum analyzer by using many-phonon scattering of light in crystals with a high coefficient of acousto-optical quality. It is experimentally shown that the relative forbiddenness of many-phonon processes in the Bragg mode can be removed by selection of scattering geometry, resulting in effective second-order and third-order scattering of light. Models of acousto-optical spectrum analyzers based on a TeO_2 crystal are described that have 2-3 times the frequency resolution of analogous devices based on one-phonon scattering with the same dimensions of the acoustic line. Figures 3, references 8.

UDC 535.241.13:534

CALCULATION OF THE PARAMETERS OF ACOUSTO-OPTICAL INTERACTION IN CRYSTALS BY THE METHOD OF PERTURBATIONS

[Paper by A. S. Shcherbakov]

[Text] An examination is made of one possible method of determining the parameters of acousto-optical interaction in crystals for arbitrary scattering geometry. Covariant relations are found for the band of acousto-optical interaction, the index

of phase modulation and the effective photoelastic constants in the case of an anisotropic medium, and expressions are derived for the effectiveness of Bragg many-phonon scattering of light. The paper uses the perturbation theory method of infinite series expansion of a one-frequency wave function with calculation of sample sums of the resultant series based on elements of the Feynman diagram method. Figures 2, references 16.

UDC 621.396.67:535.241.13:534-8

AN EXPERIMENTAL STUDY OF AN OPTICAL SYSTEM FOR PROCESSING SIGNALS IN ANNULAR ARRAYS

[Paper by I. A. Vodovatov, M. G. Vysotskiy, N. A. Yesepkina and S. A. Rogov]

[Text] An experimental investigation is made of a system for optical processing of signals in annular antenna arrays. Operation of the processing system is considered both in the static mode (with a static transparency as the input signal), and in real time using an ultrasonic light modulator. Results are given on signal processing with amplitude weighting. A discrete multichannel standard raster is used to record a holographic filter. Figures 4, references 4.

UDC 621.396.67:522.59:535

ON THE PROBLEM OF OPTICAL MODELING OF THE FIELDS OF APERTURE ANTENNAS

[Paper by G. K. Vinogradov, I. A. Vodovatov, M. G. Vysotskiy and T. I. Zubkova]

[Text] An examination is made of conditions of similarity of fields in optical and radio systems for some specific optical modeling arrangements. On this basis estimates are made of the accuracy of alignment of individual elements in optical modeling systems. Figure 1, references 4.

UDC 621.372.82:621.383.8

DIFFUSION OPTICAL WAVEGUIDFS IN LITHIUM NIOBATE

[Paper by Ye. T. Aksenov and A. A. Lipovskiy]

[Text] An experimental study is done on the feasibility of making optical waveguides in lithium niobate plates of Y + 36° and X cuts by exodiffusion in atmosphere and by diffusion of Na^+ ions. It is shown that the characteristics of the resultant optical waveguides are close to those of waveguides produced by exodiffusion in vacuum and diffusion of Ag^+ ions. The investigated methods of forming optical waveguides are technologically simple and economical. Figure 1, references 6.

UDC 621.373.826:621.397.22

USING WIDE-BAND ACOUSTO-OPTICAL ELEMENTS IN LASER VISUALIZATION OF A TELEVISION IMAGE

[Paper by Ye. T. Aksenov, N. A. Bukharin, A. B. Ignatov, N. V. Kiseleva, N. F. Maron, R. P. Seysyan, S. D. Uman, L. L. Shapiro and D. Yu. Shustarev]

[Text] Experimental data are given from a study of a system for laser visualization of television images in which the laser beam is controlled by an acousto-optic

modulator and a deflector with compound sectionalized piezoelectric transducers that enable scanning of the acoustic beam. It is shown that such systems can produce television images with better quality than conventional electronic television systems. Figures 3, references 10.

UDC 535.421

DIFFRACTION OF LIGHT ON RELIEF GRATINGS IN THE REGION OF TOTAL INTERNAL REFLECTION

[Paper by S. T. Bobrov, M. M. Butusov, V. A. Ovchinnikov, Yu. G. Turkevich and Yu. P. Udoyev]

[Text] The authors study the angular dependences of diffraction efficiency of relief gratings with spatial frequencies of 900-1700 lines/mm and relief depth of 0.02-0.4 μm. Measurements were made on $\lambda = 0.6$ μm with illumination of the grating from the backing side. It is established that close to the critical angle of total internal reflection the angular dependences of efficiency contain a structure with form depending on the polarization of the incident wave, period and depth of grating relief. Possible mechanisms of arisal of this structure are discussed. Figures 3, table 1, references 15.

UDC 778.38

METHODS OF GETTING HIGH-RESOLUTION HOLOGRAPHIC IMAGES OF MICRO-OBJECTS

[Paper by A. V. Sokolov and V. N. Bykov]

[Text] An investigation is made of the feasibility of using methods of optical holography for direct registration of micro-objects, their microstructure and spatial configuration are studied, and also the dynamics of processes in systems of micro-objects. A classification of micro-objects is given that is based on their light-scattering properties, an examination is made of the conditions of formation of images in registration by Lippmann holography and by lensless Fraunhofer holography, and recommendations are made on choosing arrangements of holographic recording depending on types of micro-objects and their configuration in the volume to be studied. Figure 1.

UDC 533.9

ON THE QUESTION OF REALIZING THE MODE OF 'SLOW BURNING' OF AN OPTICAL DISCHARGE

[Paper by L. N. Pakhomov, V. Yu. Petrun'kin and V. A. Podlevskiy]

[Text] Two versions of circuits are proposed for maintaining combustion of a plasma of an extended optical discharge that are based on the peculiarities of the design used for the cavity and the Q-switch. Results of experiments are given. Figures 3, references 2.

UDC 681.121:539.143.43

AN AMPLITUDE-MARKER NMR FLOWMETER

[Paper by V. I. Dudkin, V. V. Semenov and L. I. Uspenskiy]

[Text] This paper describes an amplitude-marker NMR flowmeter utilizing the effect of parametric resonance in the flowing liquid. It is shown that introducing magnetic field modulation in the sensor of the nutation magnet causes a characteristic change in the form of the nutation line, which extends the functional capabilities of the device. Figures 2, references 6.

UDC 621.373.823:621.317.444

A NUCLEAR MAGNETOMETER WITH AUTOTUNING BASED ON A MASER WITH CIRCULATING FLUID

[Paper by V. I. Dudkin, V. V. Semenov and L. I. Uspenskiy]

[Text] The authors consider problems of constructing an automatic magnetometer using the NMR effect in a flowing liquid. An experimental study is done on a model of a self-generating magnetometer based on a maser. The prototype instrument was used to measure variations in the intensity of a magnetic field of 600 ± 30 oersteds. The relative error of measurements is no more than 10^{-6} for the case of measurement of a magnetic field with frequency $\omega \geqslant 1$ rad/s and amplitude of 30 oersteds. Figures 2, references 8.

UDC 539.184:535.21

COMBINED EXCITATION OF SPIN PRECESSION IN A GROUP OF OPTICALLY ORIENTED ATOMS

[Paper by V. V. Semenov and I. V. Sergeyeva]

[Text] A theoretical and experimental study is done on excitation of spin precession in a group of optically oriented atoms of cesium during magnetic resonance under conditions of intensity-modulated detecting resonant radiation. The observed signals are calculated for the case where a system is exposed to the combined action of optically oriented atoms of a radio-frequency field and an intensity-modulated detecting light beam. An experimental estimate is made of the results. Figures 3, references 3.

UDC 621.373.8

ON THE PROBLEM OF THE ABSORBED POWER OF OPTICAL RADIATION IN QUANTUM FREQUENCY STANDARDS

[Paper by B. G. Matisov and I. N. Toptygin]

[Text] The constants of population are calculated in the first nonvanishing approximation with respect to the small parameter μ/ν for a three-level system that interacts with resonant r-f and optical pumping fields. This enabled enlargement of the previously developed theory of absorption of optical power by a system in the presence of an r-f field down to vanishingly small r-f amplitudes. Figure 1, references 4.

UDC 539.183.184

CALCULATION OF ADIABATIC AND NONADIABATIC COLLISIONAL BROADENING OF hfs LINES OF ALKALI ATOMS IN A BUFFER GAS ATMOSPHERE

[Abstract of paper by Vl. V. Batygin, M. B. Gornyy, B. M. Gurevich and I. M. Sokolov]

[Text] The authors calculate adiabatic broadening of hfs lines of atoms of hydrogen, Rb and Cs due to collisions with He, Ne, Ar, Kr and Xe. Based on the nonadiabatic spin relaxation mechanism proposed by Hermann, new formulas are derived for the matrix elements of transition with and without spin flip with consideration of angular dependence. The relation between the calculated cross sections and experimentally measured quantities is discussed. Tables 2, references 15.

UDC 539.183.184

COLLISIONAL SHIFTS OF CT TRANSITION LINES, AND COEFFICIENTS OF DIFFUSION OF ALKALI ATOMS IN A BUFFER GAS

[Abstract of paper by Vit. V. Batygin, Vl. V. Batygin, M. B. Gornyy and B. M. Gurevich]

[Text] Results of measurements of shifts of the CT transition line of alkali atoms (A) in a buffer gas (B) are used to plot a curve for frequency shift as a function of the ratio of ionization potentials (I_b/I_a). The shifts do not differ excessively from the experimental values. Based on the correlational theory of line shape, an estimate formula is found for calculating frequency shifts of the CT transition. The curve for shifts as a function of ionization potential ratio determined from this formula agrees well with experimental curves. Calculated values of shifts agree satisfactorily with experimental data. Shifts are predicted for some A-B pairs. An approximation formula is proposed for the potential of interatomic interaction of A-B pairs. The coefficients of diffusion for a wide class of A-B pairs as calculated by this potential are approximately half the experimental values. Figures 3, references 18, tables 3.

UDC 778.38

RECORDING HOLOGRAMS IN LAYERS OF DICHROMATED GELATIN WITH A CHECK ON THE LATENT IMAGE

[Abstract of paper by A. I. Yerko and A. N. Malov]

[Text] An investigation is made of the characteristics of formation of the latent image in layers of dichromated gelatin as a function of the energy of exposure and the intensity of radiation during recording. It is experimentally shown that there is a mechanism of diffusion of charged ions from the exposed region, which causes decay of the latent image. An experimental relation is found for the way that the diffraction efficiency of the developed layer of dichromated gelatin depends on the diffraction efficiency of the latent image. Figures 2, references 5.

UDC 621.373.826

A MINIATURE HELIUM-NEON LASER FOR OPTICAL DATA PROCESSING SYSTEMS

[Abstract of paper by S. V. Pruss-Zhukovskiy, A. I. Senyukov and A. I. Shishkin]

[Text] The paper gives the results of calculations and experimental studies of the characteristics of a miniature helium-neon laser for optical data processing systems. Tests of the laser as part of an acousto-optical spectrograph on the RATAN-600 radiotelescope showed that this laser satisfies major requirements for output power, stability and reliability. References 6.

6610
CSO: 1862

NUCLEAR PHYSICS

UDC: 621.039.58

RADIATION SAFETY AND SHIELDING OF NUCLEAR POWER PLANTS

Moscow RADIATSIONNAYA BEZOPASNOST' I ZASHCHITA AES in Russian No 4, 1980 signed to press 15 Feb 80 pp 2-4, 265-267

[Annotation, foreword and table of contents from book "Radiation Safety and Shielding of Nuclear Power Plants" edited by Yu. A. Yegorov, V. P. Mashkovich, Yu. V. Pankrat'yev, A. P. Suvorov and S. G. Tsypin, Atomizdat, 1150 copies, 272 pages]

[Text] New and original works are submitted that deal with radiation safety and shielding of AES [nuclear power plants], experimental and theoretical studies of shielding, which were performed in 1977-1978.

There is discussion of the results of studies of sources of radiation and waste from functional AES, methods of estimating the activity of coolants, accumulation of active nuclides in AES personnel and a number of other questions related to radiation safety of AES. There are descriptions of the results of theoretical and experimental studies of spread of radiation in shielding, programs for the design of shielding, and information is furnished about multigroup nuclear-physical constants. Several of the articles deal with shielding materials.

This book is intended for specialists concerned with radiation safety of AES, design and estimation of shielding, as well as undergraduate and graduate students in the relevant specialties.

There are 143 figures and 47 tables. Bibliography lists 313 items.

Foreword

This collection contains original works dealing with the study of radiation safety and shielding of nuclear power plants in the USSR in 1977-1978.

The unwaning interest of specialists in these matters is attributable to the ever increasing construction of AES and the desire to render them as safe as possible, for both service personnel and the public. The data published in the literature (see, for example, "Atomic Science and Technology in the USSR," Moscow, Atomizdat, 1977) indicate that, even now, the annual

dose to which personnel is exposed does not exceed, on the average, the maximum permissible level. The rate of active waste discharge from AES and, consequently, the dose burden on the public, also do not exceed permissible levels. However, the increase in number of AES and consequent involvement of an increasing number of people in servicing AES, and construction of AES in densely populated areas prompt specialists to search for additional means of lowering exposure of personnel and rate of active discharge of waste. The new "Sanitary Rules for Designing and Operating AES" are also oriented in this direction. The works included in this collection are the result of this search. The additional means of protection, which are unquestionably available, can and must be disclosed only through a comprehensive study of the sources of radiation at AES, the causes thereof, comprehensive study of AES as the source of radioactive substances in the environment, and this will help render AES even safer, from the standpoint of radiation.

Nor has interest waned in the study of shielding, examination of passage of radiation through different media, refinement of methods and programs for designing shielding, searching for and studying new shielding materials. The results of such studies are needed by practice, since perfect protection assures safe and convenient working conditions at AES.

The collection consists of four sections.

"Studies of Radiation Safety of AES" refer to work done at functioning AES in the USSR, as well as work dealing with methods of forecasing radiation sources and radiation conditions at AES, investigation of accumulation of radiation sources in the body and setting standards for exposure levels.

"Experimental and Theoretical Studies of Shielding" refer to articles on basic and applied problems of passage of radiation through various media, as well as methods of studying shielding.

"Methods and Programs for Designing Shielding" refer to new methods, new programs for determining the spatial and energy-related distribution of radiations in shielding.

"Studies of Shielding Materials" refer to works containing information about the properties of shielding materials when exposed to radiation.

In offering this collection of articles to the reader, the editorial board hopes that the information it contains will find practical application in solving problems of radiation safety and shielding of AES.

Contents

[002-10,657]

10,657
CSO: 1840

PREDICTION OF IONIZING RADIATION TRANSFER BY PHOTOMETRIC METHODS

Moscow PROGNOZIROVANIYE PERENOSA IONIZIRUYUSHCHEGO IZLUCHENIYA METODAMI FOTOMETRII in Russian 1979 signed to press 10 Oct 79 pp 2-4, 113

[Annotation, introduction and table of contents from book "Prediction of Ionizing Radiation Transfer by Photometric Methods" by V. N. Mironov and Ye. A. Panov, Atomizdat, 1000 copies, 116 pages]

[Text] First the matter of the use of theoretical photometric methods and the theory of heat exchange for the transfer of ionizing radiation is considered and generalized. Theoretical photometry is used to analyze the radiation of volume sources and the characteristics of ionizing radiation transfer from sources with different geometrical shapes. The possibility of using photometric methods to predict the field of ionizing radiation is shown. Examples are given from the practice of design and study of nonuniformities in the biological shielding of nuclear power plants and research reactors.

This book is intended for engineers and scientific workers dealing with problems of radiation safety in nuclear power plants, the design and study of biological shielding in nuclear power plants, reactor installations, prototypes and testing units with sources of ionizing radiation. It may also be useful to students and post-graduates specializing in this field. 54 figures. 2 tables. Bibliography, 28 references.

Introduction

The study of the transfer of ionizing radiation is an integral part of research being conducted on the physics of ionizing radiations. The establishment and development of the theory of ionizing radiation transfer is based on a generalized Boltzmann equation, by means of which problems of neutron and gamma-quanta transfer in nonabsorbing, absorbing and dispersive media are solved. Advances in electrodynamics, astrophysics and other fields of physics were used in the development of the theory. But the methods of theoretical photometry and the theory of radiant heat exchange are not yet used to the proper extent in the physics of ionizing radiation transfer, even though light, heat and gamma-radiation are identical in nature. The generality of the principles of geometrical attenuation and absorption in a medium unites these forms of radiation. In many cases the angular distribution of a volume source is similar whether it be a luminous volume of ionized gas, an incandescent metal, or the active zone

of a nuclear reactor. The basis of theoretical photometry is the cosine law of radiation distribution at the surface of a radiation source. It is inherent to transfer processes of light, heat and ionizing radiations including gamma-radiation, neutrons, alpha and beta particles. The cosinusoidal surface source is universal. This source reflects the character of the angular distribution of particles escaping from a radiator surface at large angles relative to the surface normal.

The theoretical and experimental data reported in this book indicate the possible use of principles and methods of theoretical photometry (3, 24) in the physics of ionizing radiation transfer. In some cases the same methods developed in the theory of radiant heat exchange (24,25) are used.

This book generalizes the experience of the authors in applying the methods of photometry and the theory of radiant heat exchange to the solution of such practical problems as determining the source characteristics at the surface of volume radiators and predicting the radiation field from sources of different geometrical shapes and the transfer of ionizing radiation through channels, cracks and cavities in the biological shielding of reactors (1, 2, 4, 5, 9-19, 23, 26). The authors hope that the data reported in this book will help readers to creatively apply the principles and methods of theoretical photometry in different areas of the physics of ionizing radiation transfer.

Contents

[433-9342]

9342
CSO: 1840

UDC 621.039.526'534.63'56+62-5

ACTUATING MECHANISMS FOR THE CONTROL AND SAFETY SYSTEMS OF SODIUM-COOLED FAST REACTORS

Moscow ISPOLNITEL'NYYE MEKHANIZMY ORGANOV UPRAVLENIYA I ZASHCHITY DLYA NATRIYEVYKH REAKTOROV NA BYSTRYKH NEYTRONAKH in Russian 1980 signed to press 11 Nov 79 pp 2 - 3, 176

[Annotation, preface and table of contents from book "Actuating Mechanisms for the Control and Safety Systems of Sodium-Cooled Fast Reactors" by Fedor Mikhaylovich Mitenkov, Ivan Il'ich Zhuchkov, Boris Ivanovich Zaytsev and Ivan Aleksandrovich Podtelezhnikov, Atomizdat, 780 copies, 176 pages]

[Text] The book gives specific requirements for the actuating mechanisms of control and safety systems for sodium-cooled fast reactors. Detailed descriptions are given of the designs of actuating mechanisms, manufacturing technology, and the procedure and conditions for testing experimental and series-produced models.

The book is intended for engineers and technicians engaged in the design and operation of sodium-cooled fast reactors, and may be of use to graduate students and undergraduates majoring in the appropriate fields.

Tables 8, Figures 157, references 56.

Preface

Development of nuclear power in the necessary scale is impossible without extensive introduction of fast reactors that can solve the problem of providing fuel for nuclear electric facilities. The most widely studied and most promising of known fast reactors is the sodium-cooled reactor. Research and development of sodium reactors has been in progress now for a long time in many nations. By now considerable experience has been accumulated both in the Soviet Union and elsewhere on building and operating experimental and research reactors of this type. On the basis of the cumulative experience it is possible to trace the trends in development of individual kinds of systems and equipment, and to formulate recommendations that may be quite useful in making individual kinds of equipment.

In this book an attempt has been made to present on the basis of available experience the major problems of design, manufacturing technology and testing of the actuating mechanisms of regulating units, and of systems for excess reactivity compensation and safety in sodium-cooled fast reactors. Readers should certainly be interested in the description of designs of actuating mechanisms used in sodium reactors now in operation.

The authors thank V. I. Shiryayev, V. V. Stekol'nikov and O. B. Samoylov for constructive comments made in reading individual chapters of the manuscript.

Contents

[17-6610]

6610
CSO: 1862

UDC 539.12.08

DOSIMETRIC AND RADIOMETRIC MONITORING IN WORK WITH RADIOACTIVE SUBSTANCES AND IONIZING RADIATION SOURCES. (A PROCEDURAL HANDBOOK). VOL. 1. ORGANIZATION AND METHODS OF MONITORING

Moscow DOZIMETRICHESKIY I RADIOMETRICHESKIY KONTROL' in Russian Vol 1, 1980 signed to press 20 Feb 80 pp 1-3, 267-270

[Annotation, preface and table of contents from book "Dosimetric and Radiometric Monitoring" edited by V. I. Grishmanovskiy, Atomizdat, 4350 copies, 272 pages]

[Text] The book gives principles of radiation safety and principles of normalization as set down in NRB-76, presents recommendations on organization and volume of dosimetric and radiometric monitoring, outlines widely used methods of monitoring working conditions in the presence of various radiation factors, and also gives methods of monitoring total radioactivity and the activity of separate radionuclides in gaseous emissions, and in liquid and solid wastes. A separate examination is made of problems of organizing monitoring in mining work and when working with critical assemblies and stands.

For specialists on radiation safety, for scientific, technical and engineering workers in the field of organizing and implementing dosimetric and radiometric monitoring.

Preface

Dosimetric and radiometric monitoring is an important component part of the general problem of ensuring radiation safety. This book deals with the organization and practical implementation of such monitoring. The problem of ensuring radiation safety has been successfully handled as a whole in our nation, favorable conditions have been brought about for working with radioactive substances and sources of ionizing radiation. This does not diminish the importance of monitoring the radiation environment in work areas and at operator stations, monitoring the irradiation of personnel and radioactive wastes for disposal, since the results of such monitoring are the only criteria of the actual state of radiation safety. They provide a check on conformity to established norms, enable detection and timely elimination of sources of elevated radiation, allow us to account for different factors of radiation effect on workers and to take the necessary preventive measures to reduce this effect to the minimum possible values.

The monitoring of working conditions, determination of the dose of external and internal irradiation, radioactivity of wastes to be removed to the external environment and other dosimetric and radiometric measurements are handled by workers in the radiation services of the corresponding enterprises and establishments.

Over many years these services have accumulated considerable experience in dosimetric and radiometric monitoring, have developed original monitoring methods and put them to practical use, have solved a number of organizational problems, and have formulated requirements for dosimetric and radiometric equipment and instruments.

The aim of the compilers and editors of this book has been to generalize thie experience, and to give interested specialists an opportunity to use it in their own work.

The book consists of two volumes: I -- "Organization and Methods of Monitoring" and II -- "Individual Monitoring. Radiometry of Specimens."

V. I. Grishmanovskiy

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CSO: 1862

OPTICS AND SPECTROSCOPY

UDC 535

PHOTONS AND NONLINEAR OPTICS

Moscow FOTONY I NELINEYNAYA OPTIKA in Russian 1980 signed to press 19 Apr 80 pp 2-11

[Annotation, preface and table of contents from book "Photons and Nonlinear Optics", by David Nikolayevich Klyshko, Izdatel'stvo "Nauka", 3800 copies, 256 pages]

[Text] Major concepts and methods of quantum optics are explained on the basis of the example of a few optical effects. Necessary information is given in advance from quantum mechanics and statistical physics. Major emphasis is given to certain phenomena discovered in the last 10-20 years (the Brown-Twiss effect, two-photon emission, parametric and polariton scattering of light), and also to some effects that have as yet to be observed (correlation of Stokes and anti-Stokes photons, the existence of odd field moments in thermal radiation). A common feature of these effects is that photons are emitted two at a time, and the quantum properties of light show up most clearly. A concomitant examination is made of some procedural questions such as the influence that optical nonlinearity of a material has on the statistics of its natural thermal radiation. Phenomenological relations are established between observed spontaneous and induced processes (generalized Kirchhoff laws). An examination is made of possible metrological applications of such relations for absolute calibration of light sources and sensors.

Figures 9, references 189.

Preface

At first glance the title of this book seems contradictory: after all, the term "nonlinear optics" is associated with powerful laser emission that contains an enormous number of photons, and it would seem that there is no need here to take consideration of the photon structure of light. Actually most of the effects of nonlinear (and for that matter, linear as well) optics are beautifully described by the semiclassical theory of radiation in which the electromagnetic field conforms to the classical Maxwell equations, and quantum behavior applies only to matter.

However, it is difficult or impossible to interpret certain optical effects by using the classical notions, and a systematic theory must describe both atoms and light on the basis of the principles of quantum mechanics. Besides, the graphic photonic concepts are very convenient for qualitative description and classification of many optical effects. For example the effect of doubling or summation of

the frequency of light as it propagates through a transparent crystal can be taken as the result of a set of elementary processes in which two photons of the incident light merge into a single photon with the sum energy and frequency. And of course there may be the reverse process of decay of an incident photon into a pair of photons with lower energies. Such processes explain the effect of *parametric scattering of light*. In the *Raman effect*, the incident photon is converted to one with lower frequency, called the *Stokes* photon, and a quantum of excitation of matter (e. g. a phonon in the case of vibrational excitation). In addition, the photon of incident light may join with a thermal phonon and be converted into an *anti-Stokes* photon with higher frequency. In the case of two-photon absorption, two photons of incident light are converted to the excited state of an atom, molecule or crystal. Conversely, the excited atom may pass to the ground state, emitting a pair of photons.

In this book, among all the effects of nonlinear optics discovered over the past 20 years, consideration is given mainly only to those phenomena associated with pairwise emission of photons (for the sake of brevity, pairs of simultaneously arising photons will be called "biphotons"). The emission of photons in pairs (and also in triplets, quadruplets, etc.) is intimately tied up with the optical nonlinearity of matter, and this effect clearly shows the quantum properties of light. We will also discuss the "classical" effect of *clustering* of photons, which does not involve the linearity of matter, and does not require a quantum field for explanation (the Brown-Twiss effect). This clustering is nearly random, pairs of photons in ordinary light are encountered only twice as often as in a chaotic Poisson flow of sand grains (the excess is due to the wave nature of light). Let us note that two-photon absorption on the contrary leads to uniform distribution of photons in the light traveling through matter (the *anticlustering* effect) while in lasers the nonlinearity of the working substance (saturation effect) distributes the photons chaotically.

In addition to phenomena of parametric scattering and two-photon decay that have already been observed in the laser age of optics, biphotons should also be emitted in spontaneous Raman scattering of light, which has been known for a long time. As will be shown in this book, anti-Stokes photons are emitted only paired with Stokes photons at low temperatures of the scattering substance. Immediately bordering with this effect is four-photon or *hyperparametric* scattering, which differs from three-photon parametric scattering by the participation of two pumping photons in an elementary act. We will also consider some particulars of the scattering of light by *polaritons*, which occupies an intermediate position between parametric scattering and Raman scattering by ion vibrations in the crystal lattice. These vibrations are accompanied by oscillations of the electromagnetic field inside the crystal. The polariton is a quantum of the macroscopic (averaged) field, i. e. a *photon in a medium*, and therefore it is natural to call scattering of light by poaritons, and also three- and four-photon parametric scattering, *scattering of light by light in matter* (the last word distinguishes it from *scattering of light by light in vacuum* -- an extremely weak and as yet unobserved effect of relativistic quantum electrodynamics).

Parametric scattering provides the unique capability of "manufacturing" two-photon field states, and is distinguished besides by a number of interesting features. The spectrum of scattered light is nearly continuous from radio frequencies to the pumping frequency. Emission is by the entire specimen coherently, rather than independently by individual atoms, resulting in fairly sharp forward directionality

of radiation along the pumping beam. The photons of a pair fly apart at certain small angles to one another and to the pumping beam in accordance with the law of conservation of momentum when three photons interact.

The effects considered in the book are worthy of investigation not only as "exotic" manifestations of the quantum nature of light and nonlinearity of matter. They have already been put to a number of uses. Parametric scattering is the basis of a new spectroscopic method of measuring the linear and nonlinear optical properties of crystals. When powerful pulse pumping is used, this scattering is transformed to fairly intense *parametric superluminescence* that is a source of short light pulses (down to 10^{-12} s) with continuously tunable frequency. Let us note that the intensity of three-photon spontaneous parametric scattering is proportional to the pumping intensity, and therefore is observable even with non-laser light sources in contrast to four-photon scattering, which is proportional to the square of the pumping, and parametric superluminescence, which by definition depends superlinearly (exponentially) on pumping.

From the standpoint of applied nonlinear optics the effect of parametric scattering is a source of noises that limit the sensitivity of parametric amplifiers and light frequency converters, as well as the maximum stability of parametric light generators. However, quantum noises could, in principle, be put to use in the metrology of light, becoming the basis of "quantum photometry." The parametric converter is simultaneously an absolute light brightness meter, i. e. one that needs no calibration. In addition, the simultaneity and directionality of photon emission in pairs in parametric scattering makes possible a reference photon generator that emits a known number of photons.

Finally, the phenomena considered here have a certain heuristic and pedagogical value. They offer the opportunity of a graphic* example for studying nonrelativistic quantum electrodynamics, and for mastering many important concepts of theoretical physics -- Green's functions, the fluctuation-dissipative theorem and so on. Although the immediate topic of the book is fairly narrow, a rather wide range of procedural questions of the theory of interaction of light and matter is concomitantly treated. For the reader's interest, we list some of them in deliberately paradoxical form: Can an incandescent transparent substance emit light? Can the Brown-Twiss effect be described by a Kirchhoff law? Can the non-zero root-mean cube of an electric field exist in thermal radiation? Is it possible to measure the brightness of fluctuations of an electromagnetic vacuum and make a light source with a known number of emitted photons? Do the Stokes and anti-Stokes components correlate in Raman scattering of light? Is it possible to have a field state with a definite energy and an indefinite number of photons? Positive answers are given in the book to all these questions.

This book makes an attempt (perhaps the first attempt) to systematically describe the effects enumerated above, and some related ones. The title might alternatively have been "An Introduction to Nonlinear Quantum Optics." It must be stated that in known monographs on quantum optics [Ref. 1-4] the major emphasis is on the statistics of a free field without consideration of the nonlinearity of matter that leads

* Let us note that parametric scattering is easily observed by the unaided eye at a pumping power of the order of 0.1 W in the form of a ring-shaped rainbow.

to correlation of the radio-frequency components of the field. In analyzing the statistics of laser emission [Ref. 4-6] only one of the nonlinear effects is considered -- the saturation effect that stabilizes the amplitude of oscillations. Parametric scattering is described briefly only in the book by Akhmanov and Chirkin [Ref. 7] that deals mainly with transformation of the statistics of light due to induced nonlinear effects.

Major emphasis is given here to the phenomenological description of actually observable optical effects and the relations between independently variable quantities, in particular relations of the Kirchhoff law type. By establishing such relations, we can restrict ourselves to induced effects and semiclassical theories in model calculations. This book considers only the simplest qualitative micromodels that clarify the meaning and the orders of magnitudes of phenomenological parameters. More detailed calculations of various optical microparameters and macroparameters can be found in Ref. 8-17 that have come out in the last decade and a half, and deal with the interaction between light and matter. Ref. 18 can be recommended as a general introductory course that covers the principles of quantum optics and many-photon processes.

The author has attempted to present the material on an "intermediate" level (between a textbook and a monograph) and to make it accessible to students who have just completed the principles of quantum mechanics, and to experimental physicists who have had time to forget these principles. Most of the effects are described by several models, beginning with the simplest. The book begins with an introductory chapter that gives a simplified qualitative description of parametric and polariton scattering, and also condensed historical and bibliographic information. Chapter 2 then gives necessary data from quantum mechanics and statistics. Chapter 3 describes the transition from classical to quantum electrodynamics. Chapters 4 and 5 deal respectively with one-photon and two-photon thermal radiation. Here fairly general relations are established between spontaneous and induced effects that are called *generalized Kirchhoff laws*. Similar relations are used in the next two chapters as well, dealing with processes of inelastic scattering. Chapter 6 examines parametric and polariton scattering in more detail than chapter 1. Chapter 7 contains a phenomenological description of four-photon (hyperparametric) scattering and associated coherent Raman scattering. Finally, the Appendix defines the spectral Green's function for the field in an anisotropic absorbing medium.

This book is based on research done by the author in the Department of Wave Phenomena at the Physics Faculty of Moscow State University. It has been the author's good fortune to work for some years under the direction of an eminent scientist and a fascinating person -- Rem Viktorovich Khokhlov -- who together with S. A. Akhmanov founded the school of nonlinear optics at Moscow University. R. V. Khokhlov had a lot of interest in "photon" effects of nonlinear optics, and gave his approval to the first drafts of this book.

The author would like to thank N. I. Nazarova, G. V. Venkin, V. S. Dneprovskiy, D. P. Krindach, A. N. Penin, B. F. Polkovnikov V. V. Fadeyev and others who work in the Department of Wave Phenomena for their assistance and support. The author also thanks P. V. Yelyutin, Ya. B. Zel'dovich, Yu. A. Il'inskiy and R. L. Stratonovich who reviewed the manuscript of the book and made valuable comments. And finally, the author feels that part of the blame for publication of another book should go to V. B. Braginskiy, who instigated the work.

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PLASMA PHYSICS

UDC 533

PRINCIPLES OF MODERN PHYSICS OF GAS-DISCFARGE PROCESSES

Moscow OSNOVY SOVREMENNOY FIZIKI GAZORAZRYADNYKH PROTSESSOV in Russian 1980 signed to press 13 Mar 80 pp 2-6

[Annotation, preface and table of contents from book "Principles of Modern Physics of Gas-Discharge Processes", by Yuriy Petrovich Rayzer, Izdatel'stvo "Nauka", 3600 copies, 415 pages]

[Text] The book outlines the principles of present-day physics of gas discharges, and the interaction of electromagnetic fields and laser radiation with ionized gases. An examination is made of fundamental problems of the interaction of electromagnetic waves with electrons, and the kinetic equation for electrons in a field. Particular attention is given to explanation of the relation between the classical and quantum approaches to effects. A detailed investigation is made of various discharge processes: breakdown of gases, maintenance of a nonequilibrium weakly ionized plasma, maintenance and generation of a low-temperature plasma in a constant electric field, in low-frequency, microwave and optical fields. Consideration is given to the most important applications of modern physics of discharges: processes in powerful CO_2 lasers and plasmotrons. Figures 125, tables 9, references 116.

Preface

All present-day handbooks on gas-discharge physics -- by Engel and Steenbeck (1935), Kaptsov (1950), Engel (1955), Brown (1959) and some others -- were written many years ago. These books have acquired great popularity, and are being used to this day in the classroom and on the job. But since the time of their writing, gas-discharge science has taken great strides. The appearance of new and important areas of application of discharge physics in technology and in physics experiments has played a considerable part in this advance: plasmotrons, powerful gas lasers, magnetohydrodynamic generators, interaction between laser radiation and ionized gases, and much more. For example the field relating to glow discharges, one of the oldest and most traditional, has seemed to find new life in recent years in a flurry of research with emphasis on aspects of the phenomenon (instabilities and their results) that were never even considered in the books. This upheaval is due to the explosive development of powerful CO_2 gas laser technology, where the effects of instabilities have shown up.

The modern researcher is faced with a number of problems whose answers are not to be found in the old books, even though some of them can be answered. The journal

articles on discharges are literally mind-boggling with an avalanche of unordered experimental facts and isolated theoretical considerations -- the gas discharge has always been exceptional for extraordinary variety, complexity and confusion of phenomena and processes. Right now an acute need is being felt for new and up-to-date references on discharge physics which, like all good books, would be both textbooks for students and handbooks for specialists. Books on plasma physics generally gravitate toward a different plasma -- "thermonuclear", magnetized, cosmic plasma -- and we are dealing here with the "ordinary" traditional gas discharge, to which we have recently and quite unexpectedly added the area of discharges in fields of the optical band.

The proposed book is an introduction to some urgent areas of the physics of gas discharges and interaction of electromagnetic fields and laser radiation with ionized gases. The principles of construction and choice of subject matter are as follows. First an examination is made of general problems of the interaction of constant and variable electric fields and photons with electrons. This is done both on the basis of elementary concepts and with the use of the kinetic equation. Then different discharge processes are studied. Gas discharge technology has now completely mastered a number of frequency ranges: 1) the constant electric field; 2) the radio-frequency field; 3) microwave fields; 4) optical fields. According to the nature of discharge processes, we distinguish: 1) breakdown of gases, i. e. development of ionization; 2) field maintenance of a weakly ionized nonequilibrium plasma (glow type discharges); 3) maintenance and generation of an equilibrium low-temperature plasma of the arc type. In all we get $4 \times 3 = 12$ types of processes. Most of these are considered together with applications to modern CO_2 laser physics, plasmotrons and experiments on the interaction of microwaves and laser radiation with gases and plasma.

The book pursues two goals. First, to give the clearest possible presentation of problems of a fundamental nature, that have permanent significance, to make the reader permeated with the "physics" of phenomena, to give a feeling for their internal laws, to provide researchers with an accessible tool that they can use in independent work, be it theory, experiment, or engineering. With this in mind, we have not shrunk from occasional analysis of questions that may appear to be fairly well known. Our other goal is to introduce the reader to the circle of problems that are now being intensely studied by many physicists and engineers with gas-discharge science as the basis.

For many years the author has been teaching a course for students at Moscow Physico-technical Institute for the purpose of acquainting them with discharge physics in its present form, which is an integral component of broad high-quality education of the research physicist. And I am constantly faced with the difficulty of having to recommend literature for concise and effective acquisition of this branch of knowledge. Perhaps this book will partly alleviate difficulties of this kind.

Considering the nature and purpose of the book, we have not made an issue of completeness in cited references. References to original works are given only in connection with the presentation or use of specific results and facts. The references cite monographs and survey articles where detailed bibliographies can be found.

The author is deeply grateful to A. V. Yeletskiy, who read the manuscript and made a number of valuable comments, and to N. M. Serikova for considerable help in preparation of the book. ★ ★ ★ [Yu. P. Rayzer, December, 1978]

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THERMODYNAMICS

UDC 629.78:536.24

SPACECRAFT THERMAL CONDITIONS

Moscow TEPLOVOY REZHIM KOSMICHESKIKH APPARATOV in Russian 1980 signed to press 23 Jan 80 pp 3-6, 231-232

[Preface and table of contents from book "Spacecraft Thermal Conditions", by Vladimir Viktorovich Malozemov, Izdatel'stvo "Mashinostroyeniye", 957 copies, 232 pages]

[Text] Preface

Life support for the crew on a long spaceflight is one of the most important problems of interplanetary navigation. Solution of this problem is a complex job that requires considerable effort and close cooperation between biologists, physicians and engineers in various fields.

The temperature-control system (TCS) is one of the most important components of the overall life-support system that creates and maintains the conditions necessary for human life and activity in the closed confines of sealed cabins. The job of the TCS is to create predetermined temperature conditions of a spacecraft with consideration of its interaction with the crew and the ambient medium when complex extreme factors are in operation. Efficient handling of this job requires new approaches to the development, design, investigation and testing of the TCS.

It is conventionally assumed that all that is required for a normal state of health and high capacity for work of the human organism both during a mission and after return to earth is to set up constant temperature conditions of maximum comfort in the inner environment of the sealed cabin. This treats the human organism as some predefined static object. However, recent data contradict this concept. With a prolonged stay under comparatively stable ambient conditions adaptive responses of the organism may atrophy. In such a situation, even a normally permissible change in one of the parameters may lead to loss of stability of the organism, and hence to deterioration of well-being and capacity for work. Normal well-being and capacity for work depend not so much on the parameters of the ambient environment at a given time (a person may feel normal both in severe cold and in tropical heat) as on the dynamics of the variation in these parameters, on the state of the adaptive mechanisms of the organism that are determined by the conditions under which the person had previously been. Therefore the development of a temperature control system, especially for a prolonged mission, must be carried out with consideration of its mutual relationship with the human organism, the ambient environment and the

design of the spacecraft. Only an approach like this, in which man is treated as the main component of a complex system, can guarantee development of a really effective CTS that ensures normal physical condition and high capacity for work of crew members.

There is still another important feature of design of the TCS. In flight training, the crew go through special conditioning with consideration of the future conditions of their sojourn in outer space. When they are on a mission, as a rule the crew members begin preparing from the very first days of spaceflight for the return to earth with consideration of carrying out the flight program. Under conditions of manned spaceflight, the CTS may take on some functions of a trainer if it is equipped with an appropriate conditioning program and devices that determine and predict the condition of crew members and of the entire spacecraft system.

The temperature-control system is a complex made up of subsystems that are interrelated in the functional respect. Comprehensive design and calculation of a multicomponent TCS with consideration of the mutual relation between crew, environment and individual subsystems is a complicated job. The essentially unsteady nature of the principal processes that take place under all flight conditions introduces additional difficulties both in analysis and in selection of regulatory subsystems. As yet there is not adequate experience in comprehensive solution of problems of this kind. They can be solved on the basis of a new discipline that is extensively used and involves analysis and synthesis of large systems; this is the field of systems analysis [Ref. 8. 41]. The scientific (mainly mathematical) basis of systems analysis is the theory of complex systems. The division of real systems into complex and simple is to some extent arbitrary, involving as it does the significance of the part played by "general systems" questions in the study of systems. And this in turn depends on both the properties of the system itself and the goals for which the research is undertaken. With respect to the properties of a system that put it into the category of complex systems, we can say the following [Ref. 41]: "A system will be considered complex if it consists of a large number of interrelated and interacting elements. It is natural to expect that a complex system is capable of performing a complex function."

With regard to the temperature-control system of a spacecraft, we can state with certainty that it has all the major features that characterize large systems. The considerable number of intricately interacting elements, the relation to the ambient environment and to man give us a completely sound basis for putting the TCS into the category of large systems, whose design, analysis and synthesis must be based on systems analysis and the general theory of systems. However, realization of this approach requires extensive knowledge of processes that occur in typical elements as well as on the mutual relation between individual subsystems and components. Only after studying all the particulars of the processes and the mutual relations between the elements for individual subsystems and complexes, and after constructing their mathematical models can we go on to systems methods of automated design and investigation using up-to-date computer technology.

To solve complex problems of design, analysis, synthesis and prediction, it is advisable to use functional decomposition of the TCS with incorporation of the method of mathematical modeling for studying individual subsystems and elements, including man. Functional and structural decomposition of the system and the method of

mathematical modeling enable us to formulate the problem without loss of generality, to reduce its dimensionality, to work out a procedure for solution, and to get specific results on one of the functional subsystems.

The book offered to the reader's attention is an attempt to systematize the exposition of material on calculation, mathematical modeling and investigation of spacecraft temperature-control systems. The first chapter examines general problems of temperature control and a new version of system classification. The second chapter deals with analysis of external and internal temperature loads. The following chapters present different versions of subsystems for heat protection and thermal regulation. The various subsystems are investigated on the basis of methods of mathematical modeling. Mathematical models of individual elements and subsystems are given and analyzed. Methods are demonstrated for studying mathematical models of the elements and subsystems of the TCS using digital and analog computers. The last chapter deals with problems of choosing the design parameters of the TCS.

Many of the problems formulated in the book are still a long way from their final solution. However, their formulation and study show the importance and necessity of doing further research in these areas.

The author feels obligated to thank the reviewer, Corresponding Member of the USSR Academy of Sciences Professor A. P. Vanichev for a number of valuable comments and advice given in looking over the manuscript, and also Doctor of Technical Sciences Ye. N. Bondarev, Candidate of Technical Sciences S. M. Bednov, R. M. Kopyatkevich and other comrades who reviewed the manuscript of the book and expressed their wishes and suggestions, which were taken into consideration insofar as possible in the final edition of the book.

The author thanks V. S. Pichulin, A. Ya. Donov, E. A. Kurmazenko, V. A. Tomskiy, I. I. Bogachev, S. N. Loginov, S. N. Kutepov, A. G. Bruk and T. I. Baranenkova for assistance with preparation of some materials.

Without pretense to an exhaustive treatment of the topic covered, the author will be very grateful to readers for critical comments and suggestions, which should be addressed to: 107885, Moskva, GSP-6, 1-y Basmannyy per., 3, Izd-vo "Mashinostroyeniye".

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