First All-Union Symposium on Radiation Plasmodynamics (Dzhan-Tugan, Kabardino-Balkarskaya ASSR, July 1989)

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In July 1989 the First All-Union Symposium on Radiation Plasmodynamics was held. Radiation plasmodynamics studies the physical processes of the generation of strong shock waves and thermal wideband radiation in vacuum and in media of finite pressure. It also studies radiation plasmodynamic phenomena which accompany the interaction of strong electromagnetic radiation of varying spectral content and strong shock waves with matter of all states of aggregation. This field of study develops on the basis of these studies the physical and technical principles for creating new plama-photon energy devices, technological devices, and systems of highly-concentrated energy flows, which are meant to solve a number of urgent problems in quantum electronics and photochemistry, high-temperature thermal physics and radiation metrology, medical and biological studies and technology.

The program of the symposium included an examination of the following thematic directions:

—plasmodynamic sources of radiation of great spectral brightness and generators of strong shock waves;

—numerical modeling and the theory of radiation plasmodynamic processes in vacuum and in gases;

—experimental and theoretical studies of radiation plasmodynamic processes of the interaction of thermal and coherent radiation and strong shock waves with matter in various states of aggregation;

—diagnostics of radiation plasmodynamic processes;

—thermodynamic and optical properties of the radiating plasma;

—applied aspects of radiation plasmodynamics;

—radiation plasmodynamic systems for industrial use.

More than 140 scientists and specialists from 40 scientific and industrial organizations participated in the symposium, and more than 14 invited papers were given at the plenary meetings. More than 150 original communications were presented (First All-Union Symposium on Radiation Plasmodynamics: Summaries of Reports, Parts 1 and 2. Energoatomizdat, M., 1989 (poster session papers, working group reports, "round tables").

Much of the principally new physical results of research recently published in the periodical press in this area of knowledge indicates that fundamental and applied research in many areas of radiation high-temperature and low-temperature plasmodynamics (and corresponding technical developments) are being actively conducted; main efforts are concentrated now not only on practical implementations and the technical testing of known schemes of high-current radiation plasmodynamic discharges and technical devices based on them, as well as plasmodynamic methods of heating accelerated flows of radiating plasma, but also on the search for and study of new physical principles of generating high-luminosity radiation and the development of non-traditional approaches to the problems of increasing the efficiency and energy characteristics of plasma radiators (wideband and coherent) and generators of strong shock waves, new principles for controlling their spectral-brightness and emission characteristics, and adequate theoretical description of the entire complex body of radiation plasmodynamic processes occurring in them. Especially interesting and promising great technical results is the development of principally new and synergetic approaches to the problem of multifactor radiation plasmodynamic interaction of accelerated plasma and low-energy radiation flows with matter of all structures of aggregation, which are formed by new plasmodynamic devices in previously unachieved spectral-energy and dynamic regions.

There is a wide spectrum of physical and technical achievements providing for the development of radiation plasmodynamics itself, as well as new scientific directions, both allied and associated fields (progress in which is linked with the introduction of methods of radiation plasmodynamics). Results have obtained scientific recognition and are attracting the critical attention of specialists: We note among the latter only a few of general physical interest:

General physical notions have been developed on high-current radiating plasmodynamic discharges, as an independent class of gas discharges with extremely high energy contents and forces of the quasi-steady-state current. The conditions of unification of various forms of plasmodynamic radiating discharges (where the decisive effect on impedance (volt-ampere characteristics), stability and macrostructure of the main stages of discharges, heating of plasma in radiation waves, etc. is due to radiation plasmodynamic processes) have been defined. The conditions have been formulated for their multi-parameter criteria description and association with traditional types and forms of discharges. It has been established that due to active processes of light erosion of all elements of the gas discharge tract in plasma devices when there is an increase in the density of energy (power) introduced into the plasmodynamic discharge with a current shell, and a development occurs of a broad spectrum of instabilities, affecting the macrostructure, they must necessarily switch to a mode of plasmodynamic discharges with quasi-steady-state plasma flow. This leads to new concepts in the theory of scaling and practical use of this class of discharges with extremely high energy content and of technical devices based on them (relsotron type microbody accelerators, pinch generators of hard X-ray and neutron radiation, electromagnetic shock tubes, etc.);

—A law has been established on the similarity of electronic and optical spectra of a dense plasma with respect to ion charge, which considers the effect of its nonideal nature on its optical properties, the ionization content, relaxation of its nonequilibrium state, and the electronic spectrum of negative energy in a nondegenerate plasma of multiply charged ions. This makes it possible to consider quantitatively the influence of all these effects on the thermodynamic and transport properties of dense multiply-ionized plasma. The similarity of spectral dependences of the photoionization cross sections of the ground and excited states of atoms and ions has been found, which made it possible to obtain a number of convenient analytical approximations of the cross sections of many states, which are needed to analyze the optical properties of a plasma in the ultraviolet and vacuum-ultraviolet regions of the spectrum. The effect of turbulent modification of dynamic, thermodynamic, and optical characteristics of hypersonic dense plasma flows has been detected and described, which, due to turbulent transport of mass, momentum, and energy, sharply increases the optical density of the plasma-gas boundary regions in the visible and near ultraviolet regions of the spectrum. Simultaneously the absorption coefficients in the vacuum ultraviolet decrease (the formation of transparency "windows" in the vacuum ultraviolet), which greatly facilitates the transport of vacuum ultraviolet radiation from plasma into the undisturbed gas. This leads to new designs and principles for the control of the emission spectrum in the shortwave region of the spectrum, and allows one to construct shortwave plasmodynamic radiators with a finely regulated emission spectrum;

—The radiation modes of plasma movement were systemized and studied, and this presents principally new opportunities to control the emission spectrum, macrostructure, and efficiency of the transformation of energy stored in an accumulator and the power of high-brightness radiation in a wide range of the spectrum, including the soft X-ray region. A number of vacuum sources of ultraviolet and vacuum ultraviolet radiation at the gigawatt level of pulsed power were implemented and studied. This radiation had a tunable emission spectrum and a light efficiency of 40–60 percent. Lamp-type plasmodynamic radiators were also developed with the highest values of brightness temperature ($\gtrsim 40$ kK) of radiation in the shortwave region of the spectrum with non-self-consistent introduction of energy into the plasma medium. Significant progress was made in studies and developments of compact radiators based on plasmodynamic discharges both in vacuum and in gases with magnetocumulative sources of energy. Highly efficient radiation plasmodynamic secondary standards of spectral brightness were developed in the vacuum ultraviolet as well as standard generators of strong shock waves for gas-plasma media of normal and high pressure of varying chemical and ionization content and degree of vacuum;

—Radiation-plasmodynamic methods have been used rather fruitfully in quantum electronics to produce and develop fundamentally new designs for tunable gas and plasma lasers in the ultraviolet and visible, as well as photochemical reactors, in medical and biological practice (plasma sterilizers and devices for bactericide processing, plasma surgical complexes, etc.).

A characteristic feature of the current stage of development of radiation plasmodynamics is the rather rapid application of the results of fundamental and applied research to the development of specific technical devices: machines, instruments, and test units for various purposes. This stable trend is illustrated by fundamental, primarily experimental, studies of radiation plasmodynamic processes which accompany the multifactor interaction of wideband thermal radiation and strong shock waves with matter in all sorts of states of aggregation and structure;

—Studies of radiation plasmodynamic electromagnetic and thermo-mechanical processes of the action of strong flows of thermal radiation and strong shock waves on solid matter (and the transport of selective flows of radiation through optically transparent materials) have led to new ideas on the construction of devices, such as plasmodynamic sources of radiation in the vacuum ultraviolet and soft X-ray range of the spectrum (based on plasmodynamic discharges with axial limitation of the hypersonic flows of dense plasma), devices for the light erosion processing of materials and products, effective shortwave photolithography, plasma modulators in the high-frequency and microwave frequency ranges, and secondary standards of brightness in the vacuum ultraviolet;

—As a result of experimental and theoretical studies of the thermal-acoustic processes of the interaction of strong wideband radiation with liquids with modified (in light and thermal fields) optical characteristics, quantum generators were developed based on molecules of complex organic compounds, as well as scintillators with the highest generation characteristics in the ultraviolet region of the spectrum at present. Effective devices were also developed for low-energy bactericide processing and sterilization of liquids, as well as spectral-luminescent converters in the ultraviolet, and equipment for pulse photolysis of liquids and photolytic reactors;

—The success of fundamental (primarily experimental) studies of radiation plasmodynamic processes of the interaction of powerful wideband radiation with gas media of varying chemical content in a wide range of pressures and temperatures has made it possible to implement a number of fundamentally new designs for tunable gas (excimer, photodissocation) quantum generators, photochemical reactors for various purposes, high-brightness sources of selective shortwave radiation, including excimer lamps, equipment for medical and biological purposes, technological devices for light erosion and shock wave processing and the modification of surfaces;

—As a result of the studies of the processes of the interaction of strong flows of radiation and strong shock waves with plasma media, a number of devices have been proposed for the generation of large scale artificial plasma formations, highly-efficient plasma devices which transform photon flows into electric energy, plasma photo-ionization and photo-recombination lasers, highly-efficient plasmodynamic generators of high energy density in experimental physics (the study of extreme states of matter, etc.).

The symposium was dedicated to one of the promising physical-technical directions, and its materials may be of interest to a wide range of scientists.

In 1990 Energoatomizdat will publish a collection of the scientific proceedings of the symposium (40 printer's sheets) written on the basis of survey reports at the symposium.

Translated by C. Gallant