Development of metal vapor lasers at the Siberian Branch of RAS

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The history of development and the most important results of physical investigations in the field of metal vapor lasers (MVL) at SB RAS Institutes are presented. The processes determining the inversion and energy characteristics, plasma properties of the pulse-periodic discharges, active media excitation by electron beams, constructional and technological problems of MVL realization are described. Brief information on the known and possible future MVL applications is given; issues of the day are presented.

Introduction

With the advent of optical quantum generators in the latter half of the 20th century, an intensive study of active media of different types has begun, because researchers considered lasers as possible sources of high-power radiation. It was stated very soon that energy parameters of laser media, i.e., the efficiency, the attainable power, spectral content, and some others, are determined, among others, by the structure of working particles: electronic for atoms and ions or rotational-vibrational for molecules. The potential of almost all elements of periodic table and a large list of molecules have come under the scrutiny as working particles of active media. Metal atoms and ions came in view among the first, because metal vapors traditionally were the working media of high-power high-efficiency lamps of different industrial and general purpose.

First metal vapor lasers (MVL) to a greater or lesser extent reproduced the schematic of gas-discharge He–Ne lasers; their physical schematics contained specific disadvantages, limiting energy characteristics to comparatively low level.

The ideas of using the first excited states of metal atoms in laser systems, first formulated in Refs. 1 and 2, played an important role in MVL development. Key features of the physical scheme of inversion generation, considered there, were the high quantum efficiency of lasing transitions (50% and more) and the cleaning of lower working states of atomic particles using the collision processes instead of radiation ones.

Researches in the field of MVL have been carried out at that time at the LPI RAS (group of G.G. Petrash), the Rostov State University (V.S. Mikhailevskii and then M.F. Sam, et al.), and at the IAO SB RAS (group of P.A. Bokhan).

The most important result of the researches was the observation of many lasing lines in metal atoms and ions, excited in pulse gas discharges. The lasing transitions were characterized by a huge amplification per unit length of the active medium.

Another turning point in MVL development was the discovery of the pulsed periodic excitation mode of MVL operating on transitions from resonance states to metastable ones of atomic particles at the current pulse front and attaining of high-watt average lasing powers.[3] Beginning from this time, large research commands both in the former USSR and abroad set about the study of physical processes in MVL and their prospects in different scientific and industrial areas. Similar pulse-periodic excitation mode was realized for many MVL media, including photorecombination discharge-afterglow lasing MVLs.[4]

This work presents a brief story of metal vapor laser development at the SB RAS, the most essential results of physical research of active media, design and technology problems of MVL instrumental implementation; and demonstrates the range of known and possible future MVL applications.

1. Historical information

Metal vapor lasers have been studied at the Institute of Atmospheric Optics SB RAS for about 40 years. The problems of their design and application have been treated at the Institute of Monitoring of Climate and Ecological Systems (earlier SDB "Optika") since 1974 and at the Institute of Semiconductor Physics SB RAS since 1980. At present, the investigations in the field of MVLs are conducted at the Tomsk State University (group of A.N. Soldatov) and the Tomsk Politechnical University (group of G.S. Evtushenko).

The past period of MVL development included theoretical and experimental investigations of different phenomena observed in MVLs and experimental design of laboratory samples of

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different MVLs with simultaneous study of prospects of their use in the science and practice.

More than 600 papers on the problem were published by researchers of the SB RAS in Russian and foreign journals, four doctoral theses were defended, and investigation results were systematized in two monographs.[5,6]

At present, an essential expansion of fundamental researches should be noted, while the range of practical applications of MVLs is noticeably shortened. The latter is concerned with high prices of the MVLs themselves and their operation. At the IAO SB RAS, the researching group headed by V.O. Troitskii is focused on hybrid lasers and metal-halide active media as a promising direction in design of cheaper devices. The group of P.A. Bokhan at the ISP SB RAS studies the possibilities of widening of MVL excitation conditions (e-beams, high pressures) and successfully participates in the AVLIS project (Atomic Vapor Laser Isotope Separation). The group of A.N. Soldatov at the Tomsk State University progresses in obtaining high powers in the middle IR range and studies the radiation interaction with biological materials. The group of V.V. Tatur at the IMCES SB RAS investigates the problems of producing MVL power supplies free of thyratrons in discharge plugging charts.

A limited volume of this paper does not allow even brief description of all the performed investigations. We give the most interesting (from our point of view) theoretical and experimental results in the MVL area obtained at SB RAS. Readers, who are interesting in the problem, can refer to monographs 5–9.

2. Design, material, and technology problems of MVL active media

Main problems of the design, used materials, and technology of MVLs are connected with input of metal vapors in low-temperature nonequilibrium plasma. We briefly describe the problem.

2.1. A choice of materials for the discharge channel

Vapor pressures of most elements are quite low, hence, the discharge channel has to be of a high temperature. However, the electroconductivity of dielectric materials, used in producing of discharge channels, increases with the rising temperature. The discharge channel, walls of which are produced of materials with a high conductivity, by-passes the discharge space. Hence, the most important property of the channel material must be its low electroconductivity at a high temperature. Evidently, the vapor density of the material, used for the channel producing, and its temperature modifications have to be much less than the working metal vapor density. A channel material should not form eutectic mixings with other materials, with which it contacts at working temperatures due to constructional conditions in producing the channel. The thermal widening of the channel material should not be significant and catastrophically influenced by the material recrystallization. The analysis of known materials shows that today only Al_2O_3 and BeO ceramics answer these requirements.

2.2. Retention of vapor in the discharge channel

A significant density of metal vapors in the discharge channel can be provided due to either keeping all the channel walls, including windows, at the working temperature, or by filling the channel with some buffer gas at the pressure, maintaining the diffusion motion of vapors from their source to the channel cold parts. Vapor retention through filling the discharge channel with some neutral gas is used in MVLs. For self-heating active elements, the discharge in the neutral gas is a source of heat required for initial heating of the channel.

2.3. Thermal widening of the channel

A BeO-ceramics discharge channel of 1 m in length becomes about 1 cm longer when heating from the room temperature to 1500 °C (the working temperature of the copper vapor laser). Significant thermal displacement of the channel due to its widening causes difficulties (growing with the channel length increase) for its mechanical fastening and joining with other construction units.

2.4. Thermal insulation

Thermal insulators should keep their properties at working temperatures without forming the eutectic with the channel material. The choice of thermal insulator materials is limited to Al_2O_3-based powders for Al_2O_3-ceramic channels and ZrO_2-based powders for BeO-ceramic ones.

A simplified diagram of a sealed off self-heating active element of a copper vapor laser made at the SDB "Optika", SB RAS, with a working life of about 500 h (1974–1980) is shown in Fig. 1. Satisfactory solutions of the above problems were found when the element designing.

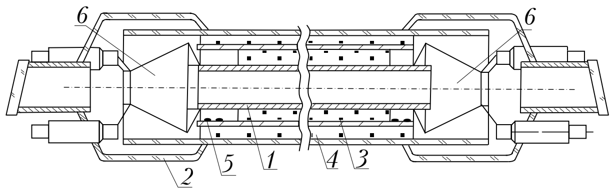

Fig. 1. Active element of a copper vapor laser (SDB "Optika" SB RAS): discharge channel (*1*); quartz vacuum covering (*2*); ZrO_2 powder (*3*); fibrous thermal insulator (*4*); containers with metal (*5*); electrodes (*6*).

The construction peculiarity is intravacuum location of the double-layer thermal insulator. Intravacuum location of a cellular thermal insulator is widely used in electrical engineering as an effective thermal insulation of cathode assemblies in electric vacuum devices.

These active elements were components of the first copper vapor lasers "Milan" (SDB "Optika").[10,11]

The experience of IAO SB RAS and SDB "Optika" in design of MVL active elements was taken into account in designing industrial sealed off MVL elements at FSUE "SPE "Istok"" (Fryazino), the unique on a worldwide scale.

2.5. Polychromatic lasers

A feature of MVL at atomic transitions from the resonance state to metastable one is a uniform mechanism of inverse populating, when laser transition excitation conditions are virtually identical by the excitation pulse and discharge parameters. The breakdown plasma in vapors of some elements does not absorb laser radiation, generated by other elements; laser media are characterized by large attenuation coefficients. All these allowed one to design a several metal vapor laser with a broad radiation spectrum operating in one discharge channel.

The investigations show that active media, produced by mixing vapors of several metals in one volume, are ineffective because of differences in excitation and ionization potentials and in temperatures, at which the concentration of normal atoms of every element is optimal. The way of polychromatic multielement lasing is suggested in Ref. 12, based on spatial spacing of active media consisted of vapors of different metals in the volume of one discharge channel.

Table below presents the parameters of the laser with Cu and Au vapor active media at different parts of one discharge channel.[5]

Table. Parameters of a trichromatic Cu and Au vapor laser

Active volume, cm^3	p_{Ne}, torr	f, kHz	C, pF	P_{λ_1}, W	P_{λ_2}, W	P_{λ_3}, W	P_{Σ}, W
94	9	15	3.2	2.20	1.04	0.72	3.95
	33	15	3.2	1.52	0.98	0.23	2.73

N o t e . $\lambda_1 = 510$, $\lambda_2 = 578$, and $\lambda_3 = 628$ nm; p_{Ne} is the buffer gas density; P is the average radiation power.

Stable lasing is obtained simultaneously at seven spectral lines in a laser with three active zones, formed by Cu, Ba, and Pb vapors. Works of SB RAS institutes in the filed of polychromatic Cu and Au vapor lasers were used to investigate their possibilities in medicine and navigation (see below) and were taken into consideration when designing commercial lasers of such type.

2.6. Lasers with modified kinetics

One of the directions of MVL development at SB RAS is the study of active media through input in them of different admixtures. Such admixtures change physical and chemical processes in the active laser medium. The goal of this direction is determination of conditions, leading to enhancement of the power and lasing efficiency. Probable positive effect of admixtures on processes in active media was theoretically justified in Ref. 13. Such MVLs were called lasers with modified kinetics (MVL-MK). The Cu + Ne vapor laser with hydrogen addition to the active volume was among the first.[14]

The MVL-MK laser class[15] includes the group of MVLs with enhanced kinetics (Kinetically Enhanced Lasers), hybrid lasers (HyDBrID-Laser), and metal vapor halide lasers with H_2, HCl, and HBr additions, all being now under active development. Active media with admixtures are considered today as sufficiently feasible to produce sealed off samples of MVL active elements.

Metal mixture vapor lasers with neutral gases, in particular, Cu vapor lasers, require high temperature of the discharge tube walls. At the same time, gas discharge lamps emitting metal atoms and ions, are well known, in which metal atoms are obtained through vapor dissociation of chemical compounds. The study of MVL active media with metal vapor input into discharge due to the dissociation (MHVL) is the priority area of investigations of all the above-listed researching commands. Their investigations are aimed at detection of intense consumption of working compounds, working out of the technique for stabilization of the active-medium gas composition, increasing the specific energy output, etc.[15] As a result of the studies, laboratory samples of single-channel active elements for an average power from 3 to 30 W (Fig. 2) were designed. The bench pilot samples of active elements emit up to 100 W.[16]

Fig. 2. MHVL active elements.

2.7. Lasers with controllable parameters

Analysis of self-heating lasing mode of MVLs elucidates the problem of maintenance of the active medium temperature, and, hence, laser energy and power when varying the excitation pulse frequency. A solution of this problem can be the separate optimization of wall heating and active medium excitation. Such optimization in the self-heating lasers with active elements, characterized by high thermal inertia, can be done via superposition of two pulsed-periodic discharges in the active volume. One discharge provides for optimal lasing excitation in every current pulse, another one stabilizes energy input into the active volume at pulse frequency variations of the first discharge.

To realize this idea, many experiments were conducted. Figure 3 presents the oscillogram illustrating the superposition of additional pulse train to MVL discharge gap in order to control the radiation power and chrominance.

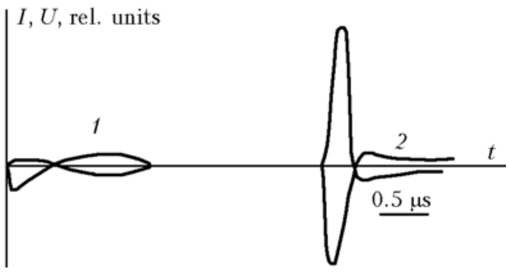

Fig. 3. Oscillograms of the active element electrode discharge current (positive signal polarity) and voltage when superposing additional (*1*) and master (*2*) exciting pulses to control the radiation power and chrominance.

These experiments have shown that this approach allows one to stabilize the thermal balance of an active medium, vary the laser radiation wavelength, generate radiation with a small divergence angle, and to control for the pulse form and length within some limits.[17–19] Such lasers are not as yet put into commercial production.

3. Study of physical processes determining inversion and power in MVLs

High output characteristics and observable huge values of amplification in the MVL active media including Cu vapor lasers, for long time allowed one to believe that a significant population inversion takes place at laser transitions at the excitation moment. However, attempts of obtaining generation at the copper transition $P^0_{3/2}-D_{3/2}$ ($\lambda = 570$ nm) failed. To resolve this contradiction, different explanations were attracted, e.g., transition competition.

As well, the method of resonance optical effect was suggested to estimate the inversion at laser transitions.[20] This method differs from traditional ones by the way of finding the value of laser-field perturbation of working state populations: from kinetic equations instead of balance ones. This method does not require the use of low-accurate atomic constants (e.g., transition probabilities).

The comparison of calculated and experimental results on population perturbations of Cu atom working states for different models of excitation processes (in the presence or absence of saturated light field) has shown that at the gas-discharge excitation the populations of Cu atom metastable states exceed the resonance ones. The inversion at $P^0_{1/2}-D_{3/2}$ and $P^0_{3/2}-D_{5/2}$ transitions is relatively low, it is determined only by a favorable ratio of statistical weights of resonance and metastable states, while the inversion at the $P^0_{3/2}-D_{3/2}$ ($\lambda = 570$ nm) transition of Cu atom with equal statistical weights of working states cannot be reached. Note, that the degree of population approximation to the inversion at a spectral transition with levels of equal statistical weights can serve a measure of optimality of the laser active medium excitation conditions.

The results of investigation allowed understanding of the MVL active media properties; as well as classifying of chemical elements according to their principal prospectivity based on a somewhat unusual criterion: the values of moments of momentum of atoms and ions in their ground states.[21]

A similar approach based of resonance optical effects was used to study the optogalvanic effect in MVLs.[22] It was found, that this effect in a Cu-vapor laser has a small amplitude (less than 1%). The use of the effect in problems of control for laser radiation is questionable.

Input of many-kilowatt powers into MVL discharge channels of about 8 cm in diameter produces significant gas temperature differences between the discharge axial parts and the wall. These differences result in radial inhomogeneity of the medium excitation and even in its overheating at the axis. The pulsed-periodic character of the power input into gas at a high excitation pulse frequency allows one to solve the problem of active medium gas temperature within the time-averaged energy input. However, this approximation does not describe medium temperature at small pulse excitation frequencies. So, the technique of the gas temperature calculation within the approximation of the pulsed-periodic energy short-pulse input into the gas and a self-similar solution for the diffusion equation have been developed.[13] This approach allowed the correlation of the excitation pulse frequency with the characteristic frequencies of thermal processes, such as the time of complete cooling of the cylindrical gas column.

One of the directions in physical researches and engineering development of the pulsed MVLs at SB RAS is obtaining of high radiation pulse-repetition rates (PRR). This is dictated by several reasons. First, the range of MVL applications is widen in this case; second, such approach allows the power and efficiency increase. According to the MVL physical analogue, the PRR physical barrier is determined by the sum of inverse times of the heating and cooling of electron gas. However, the question of which of numerous physical phenomena, proceeding in a particular active media, is determining in the limiting of the lasing PRR is not completely understood. This question is under discussion for forty years of metal vapor laser development. In common understanding, the reason of RPP limiting is a high residual density of lower (metastable) working states, making population inversions difficult. Later hypothesis by P.A. Bokhan is based on the fact of existence of high pre-pulse electron density in the discharge plasma; in this case, the thermal capacity of electron gas makes quick electron heating difficult and weakens the pumping efficiency of working states.[23]

Today, regular pulse repetition rates up to 230 kHz are realized experimentally in the Cu vapor laser, up to 150 kHz – in the Au vapor one, and up to 300 kHz – in the copper bromide vapor laser. Double-pulse method measurements show that the 500–100-kHz rate (close to the physical barrier) is obtainable in MVL and especially in MHVL.[24–26] Since plasma is virtually non-recombining in the 10^{-6}-s interpulse interval, new data on MVL efficiency and power are expectable.

Thus, the investigations of MVL and MHVL at high pulse repetition rates show their interesting properties, which can serve grounds for new areas of lasers applications.

4. Study of plasma of pulsed-periodic lasers

Laser physics needs were a powerful spur to study the low-temperature plasma including the pulse-periodic discharge plasma in mixtures of metal vapors with neutral gases.

Spatial density distribution of Cu atoms in the ground state and their temporal density distribution over excited states, obtained by spectroscopic methods,[27–31] are shown in Fig. 4. The Cu ground state is evidently 20–40% exhausted due to excitation and ionization.

Figure 5 shows the observed temporal behavior of the discharge current, the voltage at electrodes of active elements, the temperature T_e, and the concentration N_e. Fast growth of T_e at the leading edge of energy input into the discharge is seen; its drop after 100 ns of discharge formation follows the regularity of field strength drop. The temporal behavior of N_e with discharge formation reflects the growth of direct and step (after 30–50 ns) ionizations of Cu atoms.

The shown plasma measurement results give calibration values of physical parameters of an active medium when simulating the MVL active media; in particular, the initial conditions to restore the active media parameters before the following excitation pulse are obtained. Significant radial inhomogeneity of both plasma radiation and generation was also experimentally found.[30]

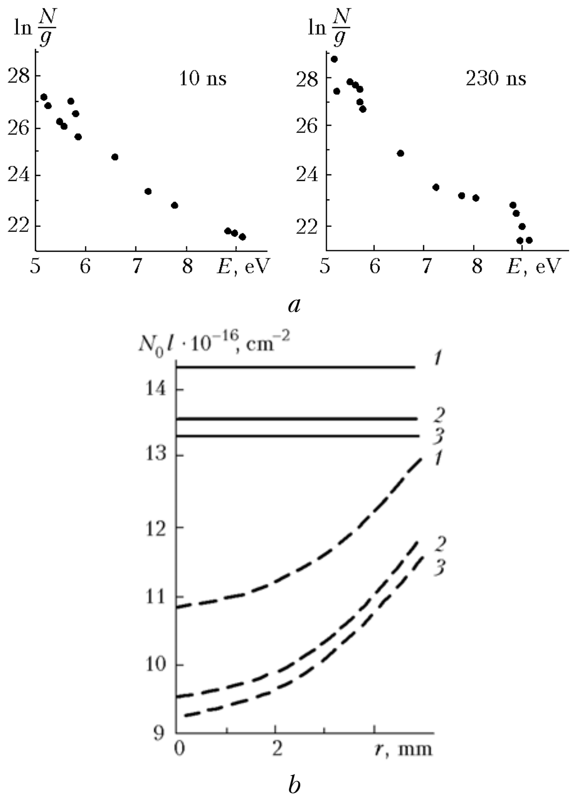

Fig. 4. Cu atoms density distribution over excited states as a function of excitation pulse development time (*a*) and over GDT (*b*) for three values of GDT's wall temperature: 1570 (*1*), 1540 (*2*), and 1530 °C (*3*). The solid curves correspond to GDT without discharge; *g* is the statistical weight; *l* is the length of main zone, cm; N_0 is the Cu atom density, cm^{-3}.

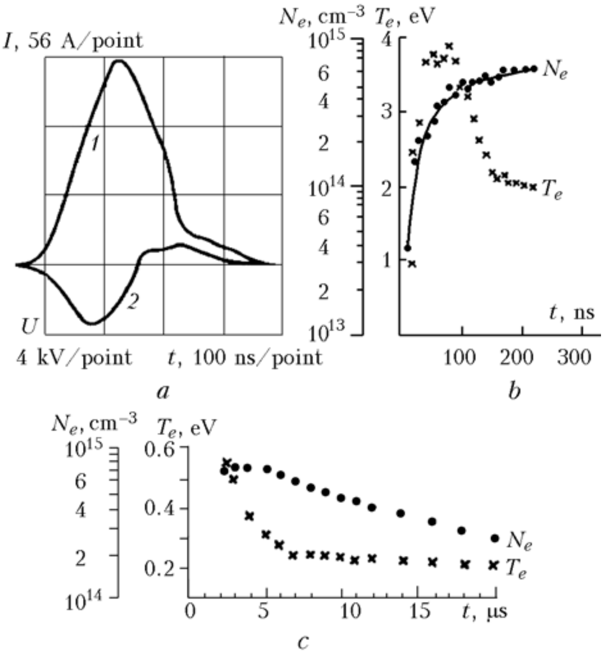

Fig. 5. Oscillograms of current pulses (*1*) and voltage (*2*) (*a*) and corresponding time dependences of the electron concentration N_e and temperature T_e (*b*); N_e and T_e in the interpulse period in the Cu laser active medium[27] (*c*).

Extensive researches of many types of non-equilibrium electric discharges in gases and gas mixtures have shown that the principal problem of high-power gas-discharge laser design is the discharge plasma instability.

In 1971, the group of G.G. Petrash at LPI RAS obtained the multiwatt lasing mode of the Cu laser and demonstrated a unique achievement in the filed of physics of non-equilibrium low-temperature plasma, i.e., the input of gigantic mean power of about 2 kW/m of gas-discharge gap into the discharge of metal vapor–neutral gas mixture[3] without gas mixture flowing.

Though many works, following Ref. 3, studied physical processes in plasma of the pulse-periodic gas discharge in mixtures of gases and vapors, the main property of this discharge, i.e., deep discharge contraction in pure neutral gases and immediate automatic decontraction when injecting vapors in gas, was not revealed by researchers and engineers for long time. The effect of the decontraction of energy-intensive pulsed-periodic discharge in a mixture of metal vapors with neutral gases was first described in 1978 by B.M. Klimkin.[31] Figure 6 illustrates this effect (photo is obtained using a transparent tube). The discharge was excited in pure He at a pressure of 150 torr by 1-μs current pulses with an amplitude of 5 A and a frequency of 10 kHz. The automatic decontraction results from the input of metal vapors into the contracted discharge in pure He (a piece of metal Eu was placed into the central zone of the discharge channel, heated with a gas burner).

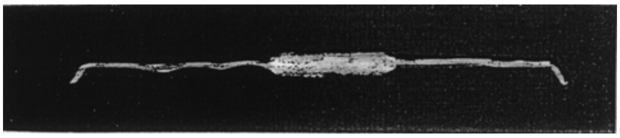

Fig. 6. Glow of pulse-periodic discharge in a tube of 1 cm in diameter, illustrating the contraction in pure He and the initial phase of discharge decontraction.

Beginning from this time, it became evident that the effect of automatic discharge decontraction was the physical ground for unique properties of a longitudinal pulsed-periodic discharge and longitudinal discharge-excited metal vapor lasers.

The power consuming and the stability of the pulsed-periodic gas discharge in mixtures of neutral gas with an easily ionized admixture are illustrated by the following experimental discharge parameters (according to published data): a tube diameter of 8 cm and a mean power of 15 kW injected into discharge per 1 m of the length of one active element. Automatic decontraction provided for the mean laser radiation power from one active element of 45 kW without gas mixture flowing.[32] Evidently, pulse-periodic discharges in metal vapors–neutral gases mixtures are now the most power-consuming and stable.

The opening of the automatic decontraction effect of pulse-periodic discharges in mixtures of neutral gas with an easily ionized admixture (Petrash effect) is, seemingly, the most valuable result in studies of pulsed-periodic MVL plasma properties.

Different points of view on the processes and causes of the contraction, decontraction, and recontraction of such discharges are presented in Refs. 33–35.

5. Beam excitation methods

Electron-beam methods of gas media excitation play a noticeable role in the gas laser physics. The physical grounds for the use of electron beams in this case are the full energy absorbability of the relativistic electron beam under conditions optimal for medium inversion. The working particle density, providing for effective relativistic electron energy absorption, is practically unattainable in MVLs. This fact drew the attention to the problems of generation of 1–10 keV electron beams and their input into gas.

One of the possible ways of metal vapor excitation by electron beams is the use of the electron run-off effect and beam generation directly in a working cell.[36] Beam generation directly in a gas medium requires additional quite complicated electrode systems in the cell. Note, that the input of electron beams into some gas medium in the form of nanosecond pulses at the rate less than plasma deionization period is a poorly investigated area of physics.[37]

The lasing in He–Xe mixture pumped by the beam of low-energy electrons was firstly observed by G.V. Kolbychev[38] after long and comprehensive theoretical and experimental studies. Lasing at self-limited transitions of Pb and Mg atoms, when beam pumping with power and higher frequency parameters as compared to similar parameters of a longitudinal discharge excited laser, was observed in Refs. 24 and 26, where the active medium was excited by radial counter-current electron flows inside a mesh anode. Cells of two types were used: one was a well-known variant of an elongated cathode with hollow anode,[39] constructed in late 1960s by I.I. Muraviev; another one contained an additional element – the ceramic tube insulator in the gap between the cathode and mesh anode. At a temperature higher than 1000 °C, the tube insulator played the role of resistor allocated over the cathode inner surface. The results of these works need in comprehensive understanding, because in some sense they contradict common concepts on the character of beam energy dissipation in a gas medium.

Thus, the works by P.A. Bokhan and G.V. Kolbychev have formed a new interesting direction in laser physics, i.e., low-energy electron beam generation and its effect on gas and plasma, and have shown the existence of new ways of MVL excitation. Practical application of the metal-vapor electron-beam excitation requires solving a number of engineering, technical, and physical problems. Two of them are the switching of pulse currents of about

10^5 A in amplitude and working frequency of 10^4 GHz, as well as the balance of energy output into an active medium and electrode system with the increasing PRR.

6. Continuous and quasi-continuous laser systems

P.A. Bokhan initiated the conceptual development and study of experimental realizability of continuous and quasi-continuous MVLs with relaxation of the lower working state at the atom–atom collisions. These works now take a noticeable place in MVL development programs of the SB RAS. The conception provided for analysis of possible schemes and mechanisms of inversion in gas-discharge plasma and the study of relaxation cross-sections. Valuable laser effects (laser radiation powers from fractions of watts to 10–15 W) in the $Ca + H_2$ [Ref. 40] and Eu + He [Ref. 41] were obtained in the course of the program. The Eu + He mixture laser system was the first metal vapor active medium, where the transition from self-limited to quasi-continuous lasing modes by means of variation of excitation conditions[41] was observed, as well as pulse-periodic lasing mode at a gas pressure of 5 atm.[42]

Laser effects in the systems of first excitation states in discharge of ytterbium, thulium, and strontium vapors in the absence of obvious electron excitation channel of the upper working state were described in Refs. 43–45.

7. Lasers in scientific and applied researches at SB RAS

7.1. MVLs in atmospheric optics

The promising areas of MVL application is atmospheric optics: spectroscopy and gas analysis of atmospheric and foreign gases, radiation propagation, and remote sensing of the actual atmosphere aiming at determination of its gas composition, thermodynamic, meteorological, and optical parameters.

Stationary and mobile Raman lidars with Cu laser as a radiation source exemplify the MVL application in lidar technique.[46] There are positive examples of the MVL use in the study of radiation transfer through dense scattering media.[47]

In navigation, laser navigators (LN) are used to solve the problems of moving object spatial orientation under limited visibility. Laser navigators "Raduga" and "Liman" with Cu and Au vapor lasers "Milan-02" and "Milan-SM" as radiation sources were designed at the IAO SB RAS and SDB "Optika."[48] The "Raduga" navigator run in the sea port Ventspils for a year, providing for passage of vessels in a narrow entrance channel of 11.4 km in length and 13 m in width under conditions of the limited visibility.

7.2. Laser separation of isotopes

MVLs, particularly, Cu vapor lasers, have the highest mean visible radiation power. In all developed countries, they are used to study AVLIS prospects and its practical application in isotope separation. This problem is under comprehensive study at the ISP SB RAS by Bokhan command. Results of their work are systematized in Ref. 6.

7.3. Lasers in medicine

Medicine, particularly, oncology, is also a promising area of MVLs application. References 49–52 and 53 present examples of such application, carried out by researchers of SB RAS and the Oncology Research Institute of the Tomsk Scientific Center of the Russian Academy of Medical Sciences.

8. Prospects of development of MVLs and laser systems

1. Experimental and theoretical study of the effect of increased power consuming and stability of pulse-periodic discharges and estimation of their use for longitudinal gas-discharge excitation of other media.

2. Detailed researches of active media, including the study of the input power-limiting mechanisms, search for ways and conditions for inversion level increase, obtaining valuable output radiation powers (dozens of W) at a PRR of 100 kHz and higher, the study of physics and chemistry of trace admixtures in MVL active media.

3. Solution of engineering and material problems of MVL active elements, technical and economical assessment of the change of vapor active elements for salt ones; design of MVL power supplies on the modern element base, among others, without tiratrons.

4. Solution of engineering, technical, and physical problems of MVL electron-beam excitation; search for new physically interesting directions in the MVL study.

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