# Optical Emission and Parameters of DBD Plasma in a Mixture of Mercury Diiodide and Mercury Dibromide Vapor and Helium with Addition of Xenon

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**Abstract:** *The spectral, energy, and electrical characteristics of atmospheric pressure nanosecond DBD plasma in HgI2 / HgBr2 / Xe / He mixtures were studied. The discharge was initiated by a repetitively pulsed voltage with a pulse repetition rate of 5-20 kHz of positive polarity, an amplitude of 25.5 kV, and a half-height duration of 150 ns. The optical emission of the exciplex molecules HgI(B2Σ+1/2-X2Σ+1/2) and HgBr (B2Σ+1/2-X2Σ+1/2)was investigated. Based on a comparison of the temporal behavior of the B-X transition spectra of the HgI (λmax.=443 nm) and HgBr (λmax.= 502 nm) molecules, the mechanism of simultaneous formation of the exciplexe sHgI \* and HgBr\* molecules is determined. Specific power radiation, namely 96 W/cm3 in a single pulse and the average, namely 260 mW/cm3 at a pulse repetition rate of 18 kHz was achieved. The distribution of the energy and rates of the processes responsible for the emission of HgI and HgBr molecules are analyzed. Studies have revealed the possibility of optimizing the pulsed power in order to obtain simultaneous emission in the visible (violet-blue and blue-green light) spectral range in the plasma of the atmospheric-pressure DBD in the HgI2/HgBr2/Xe/He mixture.*

**Keywords:** *DBD plasma, mercury diiodide, mercury dibromide, helium, xenon, optical emission*

## 1. INTRODUCTION

The emission characteristics and parameters of the plasma are important both for the improvement of existing and for the creation of new radiation sources [1-3]. Plasma in mixtures of mercury diiodide and mercury dibromide vapor with atomic gases can be an effective source of dual-band coherent and spontaneous emission in the violet-blue and blue-green spectrum with an emission maximum at a wavelength of ($\lambda_{max.}$) 443 nm and ($\lambda_{max.}$) 502 nm [4,5]. Light sources that operate on these mixtures provide high spectral radiation power, which is important for practical applications, such as sources of active photosynthetic radiation or lasers and others [6-8]. The high radiation efficiency of such mixtures was demonstrated in the studies of the authors [9–11].

This paper is devoted to the study of optical emission (350–700 nm) of a dielectric barrier discharge (DBD), which was created by a nanosecond (150 ns) pulse-periodic (5–20 kHz) high voltage in a mixture of mercury diiodide, mercury dibromide vapor with helium with the addition of xenon. On the basis of experiments and numerical calculations of plasma parameters, the mechanism of formation of exciplex molecules HgI\* and HgBr\* and additional processes that increase the population of $B^2\Sigma^+_{1/2}$ –state of mercury monohalides are analyzed.

## 2. TECHNIQUE AND METHODS OF RESEARCH

**The technique and methodology for studying the optical emission of DBD plasma in a mixture of mercury diiodide and mercury dibromidevapor, helium, and xenon was similar to that used in studies of the mixture without the addition of xenon [11].**

The investigated mixture was prepared directly in the interelectrode space. Mercury dihalides: mercury diiodide and mercury dibromide in an amount of 80 mg were preloaded into the interelectrode space. The surfaces of the elements of the internal volume of the tube were outgased by heating it at a temperature of 50° C and pumping it to a residual gas pressure of 1 Pa for 2 hours. The partial vapor pressure of $HgI_2$ and $HgBr_2$ in the mixture was created due to the heating of the mixture during the dissipation of the energy of a repetitively pulsed discharge. It was measured by the

temperature of the coldest part of the tube based on the linear interpolation of the reference data from [12]. The partial pressure of xenon and helium was measured by a sample membrane gauge and pressure gauge, respectively.

## 3. RESEARCH RESULTS AND DISCUSSION

The radiator emission spectra were studied in the region of partial pressures of mercury diiodide and mercury dibromide vapor of 0.1–0.5 kPa, xenon 0.1–4 kPa, and helium 100–180 kPa.

The survey radiation spectrum at a pulse repetition rate of f = 18 kHz is shown in Fig.1. The amplitude of the voltage on the electrodes and the current through the gas-discharge gap is 25.5 kV and 280A, respectively. The total pressure of the mixture is 181.4 kPa. A characteristic feature of this mixture is the presence of systems of spectral bands of the electron-vibrational transition$B^2\Sigma^+_{1/2} \rightarrow X^2\Sigma^+_{1/2}$ of the exciplex molecules HgI* and HgBr* 5 and 7 nm wide with radiation maxima at wavelengths $\lambda = 443$ nm and $\lambda = 502$ nm, respectively [13], a steep increase in the intensity of these spectral bands on the side of the long-wavelength region and a slow decline in the short-wave region. The edges of the spectral bands overlap the wavelength range of 350–510 nm. In addition to these spectral bands, radiation is also observed on the $\lambda = 546$ nm line of mercury atoms, the transition $7s^3S_1 - 6p^3P^0_2$, and the $\lambda = 823$ nm line of xenon atoms, transition$6s[3/2]^0_2 - 6p[3/2]_2$ [14,15]. With a change in the pulse repetition frequency from 5000 Hz to 20,000 Hz, the radiation intensity in the spectral bands and lines increases 4 times.
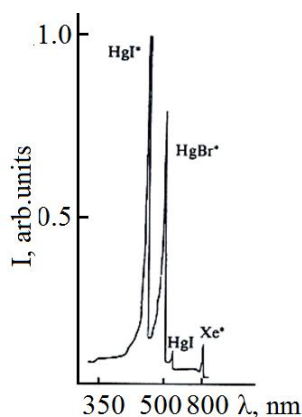


**Fig1.** *Survey plasma emission spectrum of a barrier discharge. Partial pressures: mercury diiodide — 0.1 kPa, mercury dibromide — 0.3 kPa, xenon –1 kPa, helium — 180 kPa. The amplitudes of the voltage and current pulses are 26 kV and 280 A, respectively.*

The results of studies of integral characteristics (the dependence of the average radiation power on the partial pressure of the buffer gas helium, xenon, and the time of operation of the emission source in one portion of the working mixture are shown in Fig. 4, Fig. 5 and Fig. 6. The regularity is established with increasing partial pressure of helium from 140 kPa to 200 kPa, an increase in the specific average power, the achievement of its maximum specific value of 260 mW/cm$^3$ at 180 kPa and a decrease in the further increase in helium pressure is observed.
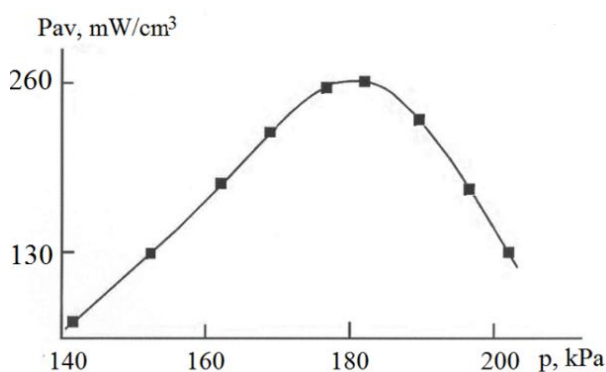


**Fig2.** *The dependence of the specific average radiation power on the partial pressure of helium. The partial pressure of xenon -1 kPa. The pump pulse repetition rate is 18 kHz, the voltage pulse amplitude is 25.5 kV.*
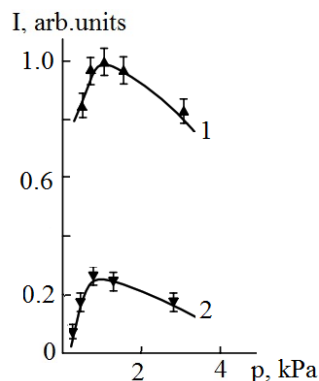
**Fig3.** *The dependence of the radiation intensity of mercury monohalides in relative units on the pressure of xenon: 1-molecule HgI\*, 2-molecule HgBr\*. Helium partial pressure is 180 kPa. The pump pulse repetition rate is 18 kHz, the voltage pulse amplitude is 25.5 kV.*

Fig.3 shows the results on the dependences of the radiation intensity of exciplex molecules of mercury monoiodide and mercury monobromide on the partial pressure of xenon. The most intense radiation of these molecules occurs at a partial pressure of xenon in the region of 1 kPa. In the mixture, mercury monoiodide molecules emit more intensively (3.5 times) compared to the radiation intensity of mercury monobromide molecules.

The dependence of the radiation intensity of mercury monohalides in relative units on the number of pump pulses is shown in Fig. 6. The saturation of the radiation power occurs for exciplex molecules HgI\* and HgBr\* after $4 \cdot 10^7$ pulses.
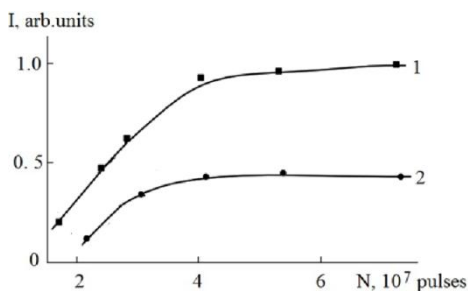


**Fig4.** *The dependence of radiation intensity of mercury monohalides on the total number of pulses: 1. HgI\* molecule, 2. HgBr\* molecule. The total pressure of the mixture is 181.4 kPa. The pulse repetition rate is 18 kHz, the voltage pulse amplitude is 25.5 kV.*

The results of studies of the temporal characteristics of the radiator are shown in Fig.5 with the most optimal radiation power for the experimental conditions. The error and reproducibility of the results of oscillographic measurements were 10% and 90%, respectively. Current pulses (I) have the different polarity. Their complex form is caused by recharging the dielectric-plasma circuit. Their amplitude and duration are ~ 280 A and ~ 150 ns, respectively. Radiation pulses (P) have the same polarity. The pulse durations at half-height were ~ 100 ns and ~ 150 ns for the HgI\* and HgBr\* molecules, respectively. The specific power in the radiation pulse is 96 W/cm$^3$.
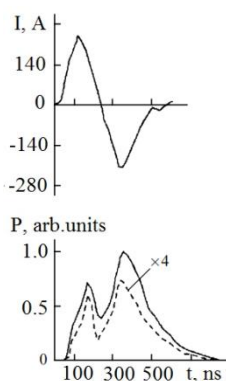


**Fig5.** *Oscillograms of current (I) and radiation (P) pulses: --- HgI\* molecule, - HgBr\* molecule. The total pressure of the mixture is 181.4 kPa. The pulse repetition rate is 18 kHz, the voltage pulse amplitude is 25.5 kV.*

Two-hump temporal dependence is observed for the emission of both HgI* and HgBr* exciplex molecules. The amplitudes of the current and radiation pulses coincide in time within the measurement error (10%). The amplitude of the second radiation pulse for these molecules is higher than the first. The second pulse is characterized by an increase in its duration compared to the first pulse.

The parameters of DBD plasma are optimal for obtaining the maximum radiation power on the mixture $HgBr_2$-$HgI_2$-Xe-He = 0.001635-0.0005513-0.005514- 0.9823 at a total mixture pressure of 181.4 kPa on the reduced electric field (E/N): were determined numerically and calculated as total integrals of the electron energy distribution function (EEDF) in the discharge. The EEDFs were found numerically by solving the Boltzmann kinetic equation in the two-term approximation [16]. Calculations of the EEDF were performed using the program [17]. Based on the resulting EEDF, mean electron energy, the specific power losses of the electric discharge on various elementary processes in the plasma, and the rate constants of elastic and inelastic scattering of electrons on mercury diiodide and mercury dibromide molecules, xenon and helium atoms depending on the value of the reduced electric field (ratio electric field strength (E) to the total concentration of mercury dihalide molecules, xenon and helium atoms (N)). The range of changes in the parameter E/N=1-100 Tд ($1 \cdot 10^{-17}$ - $1 \cdot 10^{-15}$ V·cm$^2$) and included the values of the parameter E/N, which were implemented in the experiment.

The integral of electron collisions with helium, xenon, mercury dibromide and mercury diiodide molecules includes the following processes of elastic and inelastic collisions: elastic scattering, excitation of energy states of the atom He ($2^3$S, $2^1$S, $2^3$P, $2^1$P, 3SPD, 4SPD, 5SPD), helium atom ionization , elastic scattering and excitation of electronic states of xenon atom with threshold energies: 3.4 eV, 8.31 eV, 8.44 eV, 9.69 eV, 10.0 eV, 11.0 eV, 11.7 eV, ionization of xenon atoms, vibrational excitation of $HgBr_2$ molecules, excitation ($HgBr_2$ (D)) - state of $HgBr_2$ molecules, dissociative excitation of mercury monobromide($X^2\Sigma^+_{1/2}$, $B^2\Sigma^+_{1/2}$- states), attachment, ionizationof mercury dibromide molecules, dissociative excitation of $B^2\Sigma^+_{1/2}$–state of mercury monoiodide and ionization of mercury diiodide molecules. The data on the absolute values of the effective cross sections for these processes, as well as their dependence on the electron energy, are taken from [17, 18–21].

Fig.6showsthecharacteristicviewofthe EEDF whenchangingthereducedelectricfieldstrength (E / N) intherangeof 1-100 Td. The parameters have been determined on dependence on the reduced electric field (E / N) in the range of 1-100 Td. An increase of its value leads to increase of the number of "fast" electrons in the discharge. Mean electron energy of the discharge increases sharply from 0.5 to 3.8 eV with increasing E/N from 1 to 14.7 Td. With further increase of the reduced electric field the rate of increase of mean electron energy slows down and reaches a value of 12.2 eV for E/N = 100 Td. The value of the reduced electric field at which experimental studies were carried out and the mean electron energy and their temperature is equal to 68 Td, 9.6 eV and 111360K, respectively. Theconcentration of electrons was $4.6 \cdot 10^{17}$ m$^{-3}$.
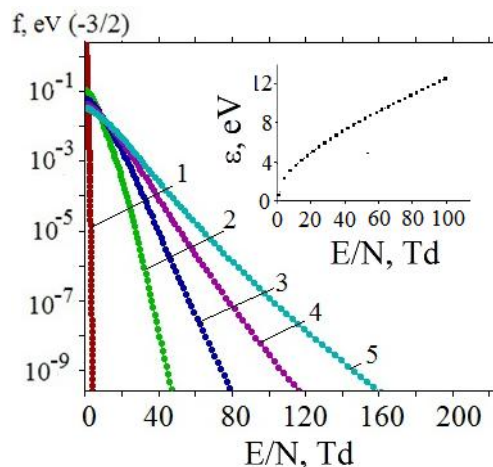


**Fig6.** *The electron energy distribution functions in the mixture: $HgBr_2$: $HgI_2$:Xe: He=0.00163 5:0.0005513:0.0 05514:0.9823 with a total mixture pressure P = 181.4 kPa for the values of the parameter E/N: 1 (1), 25.8 (2), 50.5 (3), 75.2 (4), 100 (5) Td; The inset shows the dependence of mean electron energy on the parameter E/N.*

Fig.7 shows the results of studies of the dependence of the rate constants of inelastic collisions of electrons with mercury dihalide molecules on the parameter E/N. For a reduced electric field value of 68 Td, at which experimental studies were performed, the rate constants of dissociative excitation by electrons of the $B^2\Sigma^+_{1/2}$- state of mercury monoiodide (1) and mercury monobromide (2) molecules are $2 \times 10^{-14}$ m$^3$ / s.
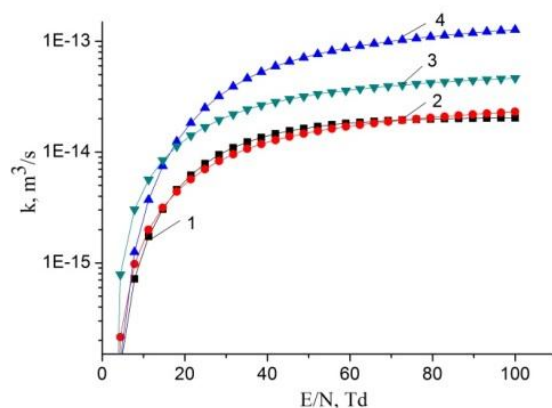


**Fig7.** *The dependence of the collision rate constants of electrons with components of a gas-discharge plasma on a mixture of HgBr$_2$: HgI$_2$ : Xe: He =0.001635:0.0005513:0.005514:0.9823 with a total mixture pressure P = 181.4 kPa on the parameter E/N: 1 - dissociative excitation of $B^2\Sigma^+_{1/2}$- states of the HgI\* molecules, 2 - dissociative excitation of $B^2\Sigma^+_{1/2}$-states of HgBr\* molecules; 3 - dissociative excitation of the $X^2\Sigma^+_{1/2}$- state of HgBr molecules; 4 - the excitation of (HgBr$_2$(D)) states of HgBr$_2$ molecules.*

The distribution of the specific power losses of the discharge on the main processes is shown in Fig. 10. The fraction of the specific power of the discharge which goes on the processes of dissociative excitation of mercury monobromide and mercury monoiodideexciplex molecules increases with the increase of the parameter E/N. It reaches a maximum of 10.6%, 25.5%, 35.7% and 3.3% with the E/N parameter equal to 21.5 Td, 18.1 Td, 31.7 Td and 18.1 Td for electronic states of mercury monobromide$B^2\Sigma^+_{1/2}$, $X^2\Sigma^+_{1/2}$, mercury dibromide (HgBr$_2$ (D)) and $B^2\Sigma^+_{1/2}$-state of mercury monoiodide, respectively, and with a further increase of parameter E/N it decreases.
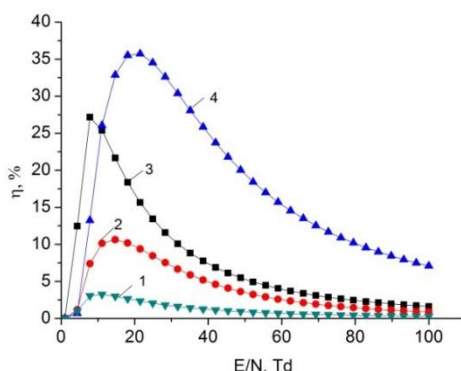


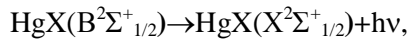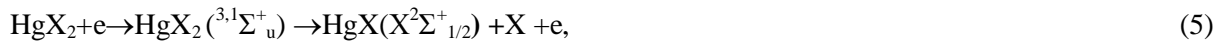**Fig8.***The dependence of the specific power losses of the discharge on the processes of electroncollisionson the HgBr$_2$: HgI$_2$ : Xe: He = 0.001635:0.0005513:0.005514:0.9823 mixture at the total mixture pressure(P = 181.4 kPa) on the E/Nparameter: 1 -the dissociative excitation of $B^2\Sigma^+_{1/2}$-state ofHgI\* molecules, 2 –the dissociative excitations of $B^2 \Sigma^+_{1/2}$-state of HgBr\* molecules, 3 – the dissociative excitations ofX$^2\Sigma^+_{1/2}$-state of HgBr\* molecules, 4-excitation of the electronicstateofmercurydibromide (HgBr$_2$ (D)).*

The emission of spectral bands and lines is probably observed due to the following reactions [16,18-24]:

$$X + e \tag{1}$$

$$HgX_2 + e \rightarrow HgX_2(^{3,1}\Sigma^+_u) \rightarrow HgX(B^2\Sigma^+_{1/2}) + \quad X^- , \tag{2}$$

$$HgX_2 + e \rightarrow HgX_2(D) \rightarrow HgX(C^2\Pi_{1/2}, D^2\Pi_{3/2}) + X + e, \tag{3}$$

$$HgX(C^2\Pi_{1/2}, D^2\Pi_{3/2}) + M \rightarrow HgX(B^2\Sigma^+_{1/2}) + M + \Delta E_{1,2}, \tag{4}$$

$$HgX_2 + e \rightarrow HgX_2(^{3,1}\Sigma^+_u) \rightarrow HgX(X^2\Sigma^+_{1/2}) + X + e, \tag{5}$$

$$HgX(B^2\Sigma^+_{1/2}) \rightarrow HgX(X^2\Sigma^+_{1/2}) + h\nu,$$

$$\lambda_{max.} = 443 \text{ нм}, \lambda_{max.} = 502 \text{ nm} \tag{6}$$

$$HgX(B^2\Sigma^+_{1/2}) + M \rightarrow HgX(X^2\Sigma^+_{1/2}) + M, \tag{7}$$

$$HgX_2 + e \rightarrow Hg^* + 2X + e, \tag{8}$$

$$Hg^* \rightarrow Hg + h\nu, \tag{9}$$

$$\lambda = 546 \text{ nm},$$

$$Xe + e \rightarrow Xe^* + e, \tag{10}$$

$$Xe^* \rightarrow Xe + h\nu, \tag{11}$$
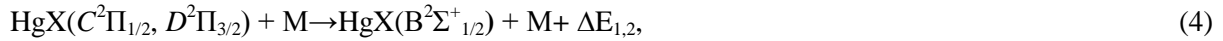
$$\lambda = 823 \text{ nm},$$

where X is a halogen atom (I, Br), M is the concentration of quenching molecules and atoms ($HgX_2$, Xe, He), respectively, $\Delta E_{1,2}$ is the energy difference in reactions (4).

Reactions (1) and (2) are the main sources of formation of exciplex molecules HgX * [18 - 23]. Their rate constant has a value $2 \times 10^{-14}$ m$^3$/s (Fig.7) for our experimental conditions with a reduced electric field strength of 68 Td.

In addition, the exciplex molecules of mercury monoiodide and mercury monobromide are formed due to reactions (3, 4) due to the excitation of mercury diiodide and mercury dibromide molecules by electrons to state D [20]. The rate constant has a value of $9.9 \times 10^{-14}$ m$^3$/s for mercury dibromide molecules (Fig.7). This state of mercury dihalide molecules is the sum of all states that are located between the threshold energy and the ionization energy. Emission from the D states of the $HgX_2$ molecules is not observed, due to the fact that these states dissociate with the formation of mercury monohalides in the (C, D) states. In our experimental conditions, emission from C and D states of mercury monoiodide and mercury monobromide molecules is not observed due to the high efficiency of the quenching process (4) (It is known that the product of the quenching rate constant by helium and xenon of $C^2\Pi_{1/2}$-state of mercury monoiodide molecules on the lifetime is equal to $4.2 \cdot 10^{-18}$ cm$^3$ and $4.2 \cdot 10^{-18}$ cm$^3$, respectively, and the process of quenching (C, D)-sates by mercury dihalides occurs more efficiently [24, 25]).The population of these states is transferred to $B^2\Sigma^+_{1/2}$ - state of mercury monoiodide and mercury monobromide molecules or to other non-optical channels [25]. The reaction of the collision of mercury dihalide molecules with electrons (5) is the channel for the formation of mercury monohalides molecules in the ground state, the rate constant of which is $3.9 \cdot 10^{-14}$ m$^3$/s (Fig.7). Electron-vibrational transitions $B^2\Sigma^+_{1/2} \rightarrow X^2\Sigma^+_{1/2}$ of mercury monoiodide and mercury monobromide molecules lead to emission of spectral bands with a maximum intensity at wavelengths $\lambda_{max.} = 443$ nm and $\lambda_{max.} = 502$ nm (reaction 6). In the quenching reaction (7), an electron-vibrational transition of mercury dihalide molecules to their ground state occurs without radiation. The rate constant of this process for quenching of mercury monoiodide and mercury monobromide molecules by helium $<2.9 \cdot 10^{-20}$ m$^3$/s and $<3.4 \cdot 10^{-20}$ m$^3$/s, respectively [25] and by mercury dihalides $1.1 \cdot 10^{-16}$ m$^3$/s and $3 \cdot 10^{-16}$ m$^3$/s [24].

Excited mercury atoms are formed due to the passage of reaction (8) due to the large effective cross section of the dissociative excitation of $HgX_2$ molecules. Their emission (reaction 9) leads to the appearance of the line $\lambda = 546$ nm (Fig.1). Reaction (10) is responsible for the excitation of xenon atoms, the rate constant, which is $\sim 1 \cdot 10^{-17}$ m$^3$/s (our calculation data). Excited xenon atoms emit quanta (h$\nu$) as a result of radiative decay as a result of which a xenon line $\lambda = 823$ nm was observed in the spectrum (Fig. 2) (reaction 10). In addition, the presence in the emission spectra (Fig. 2) of the line of Hg atoms can be caused by the process of degradation of the working mixture. Part of mercury monoiodide and mercury monobromide molecules does not have time to associate in the processes:

$$HgX(X^2\Sigma^+_{1/2}) + X_2 \rightarrow HgX_2 + X, \tag{13}$$

$$\text{HgX}(X^2\Sigma^+_{1/2})+X+He\rightarrow HgX_2+He, \tag{14}$$

dissociate into mercury and halogen atoms in collisions with electrons [26]. Halogen atoms have time to escape to the surface of the electrode and form metal halides [27,28]. Mercury atoms accumulate and, in collisions with electrons, are excited and emit radiation $\lambda = 546$ nm.

A steep increase in intensity from the part of the spectrum with large wavelengths and a slow decline in the short-wavelength region (Fig.1) for both the mercury monoiodide molecule and mercury monobromide molecule are explained by the form of potential curves (excited $B^2\Sigma^+_{1/2}$ – state is shifted towards large inter nuclear distances relative to $X^2\Sigma^+_{1/2}$ - state) and relaxation processes of the population of the upper vibrational levels of the excited electronic state, which occur faster than the electronic-vibrational transition to the main $X^2\Sigma^+_{1/2}$-state [29,30].

The regularity of the increased intensity of HgI* molecules compared to the intensity of HgBr* molecules at the same excitation rate constants ($2.0 \times 10^{-14}$ m$^3$/s, Fig.7) is caused by the quenching process of the $B^2\Sigma^+_{1/2}$ - state of mercury monohalides by mercury dihalide molecules (reaction 7). The quenching rate constant of the $B^2\Sigma^+_{1/2}$-state of mercury monoiodide molecules - is $1.1 \cdot 10^{-10}$ cm$^3$/s, and that of mercury monobromide molecules – $3.4\cdot10^{-10}$cm$^3$/s [24], which makes the difference in the emission intensities of these molecules.

The dependence of the radiation power on the partial pressure of helium (Fig.2) is caused primarily by the following processes: an increase in the electron concentration with an increase in the partial pressure of helium in the mixture, a change in the fraction of the discharge energy spent on heating the working mixture; a change in mean electron energy and the rate constant of the excitation of the exciplex molecules HgI* and HgBr * depending on the values of the parameter E/N, as well as quenching process of the $B^2\Sigma^+_{1/2}$ – state of molecules HgI* and HgBr* in collisions with helium atoms, xenon and mercury dihalide molecules. With an increase in the partial pressure of helium in the mixture, the value of the parameter E/N decreases. This leads to an increase in the specific losses of the discharge power on the elastic scattering of electrons on atoms and molecules (Fig.8) and, accordingly, to an increase in the partial pressure of mercury diiodide and mercury dibromide vapor and the radiation power of mercury monoiodide and mercury monobromideexciplex molecules. In addition, an increase in the electron concentration increases with increasing partial pressures of both helium and mercury diiodide and mercury dibromide vapor, also increases the concentration of electrons, which increases with increasing concentration of the components of the working mixture [1]. The presence of a maximum and a further drop in the radiation power of the exciplex molecules HgI* and HgBr* with an increase in the partial pressure of helium is associated with a decrease in the fraction of the discharge energy that is spent on exciting their $B^2\Sigma^+_{1/2}$ – state (Fig.8), as well as well as quenching the states of mercury monohalide molecules when they collide with helium atoms [1].

$$\text{HgI}^* + He\rightarrow HgI +He+ \Delta E_3, \tag{15}$$

$$\text{HgBr}^* + He\rightarrow HgBr +He+ \Delta E_4, \tag{16}$$

Where $\Delta E_{3,4}$ is the energy difference in the reactions.

The dependence of the intensity of the emission of HgI* and HgBr* molecules on the partial pressure of xenon (Fig. 5) is determined by the efficiency of the processes leading to their excitation and quenching — $B^2\Sigma^+_{1/2}$–states of these molecules in the DBD plasma. The quenching rate constant for xenon of HgI* and HgBr * molecules is $2.2 \times 10^{-13}$ cm$^3$/s и $3.8 \times 10^{-14}$ sm$^3$/s, respectively [25].

The earlier achievement of saturation in the intensity of HgBr* radiation from the number of pulses than for HgI* molecules (Fig. 4) is caused by a greater loss of discharge power on the dissociative excitation of $B^2\Sigma^+_{1/2}$ – state of HgBr* molecules compared to the HgI* molecules (Fig.8).

The temporal dependence of the current pulses (Fig.5) is caused by the charge exchange of the dielectric-plasma circuit. The increased amplitudes of the second radiation pulse, its duration and the duration of the falling front, as compared with the first pulse, are caused by the increase in the population of the $B^2\Sigma^+_{1/2}$- state of the HgI* and HgBr* molecules, which pass on time later than the main (dissociative excitation by electrons in collisions with mercury dihalide molecules). Such processes can be:

$$HgX^+_2 + e \rightarrow HgX(B^2\Sigma^+_{1/2}) + X, \qquad (17)$$

$$HgX^+_2 + X^- \rightarrow HgX(B^2\Sigma^+_{1/2}) + X_2, \qquad (18)$$

$$HgX(X^2\Sigma^+_{1/2}) \rightarrow HgX(B^2\Sigma^+_{1/2}) + e \qquad (19)$$

The process of recombination of positive mercury dihalide ions with electrons (17), according to the authors of [31], can play a significant role at current densities of $\sim 1000$ A/cm$^2$, which is not observed under the conditions of our experiment. The calculated rate constants of the recombination process (18) of a positive ion with a negative ion are high (for HgI$_2$ and HgBr$_2$ molecules $\sim 3\times10^{-7}$ cm$^3$/s), however, under gas-discharge conditions due to low concentrations of atomic ion (rate constant of the process of negative ions formation I$^-$ Br$^-$ $\sim 10^{-10}$ cm$^3$/s [21]) its role is negligible. The excitation of radicals HgX $(X^2\Sigma^+_{1/2})$ by electrons in the $B^2\Sigma^+_{1/2}$- state (19) is possible under our experimental conditions.

The regularity of the difference in the magnitudes of the amplitudes of the first and second radiation pulses (Fig.5) is explained as follows. The first and second excitation pulses (current) form mercury monoiodide and mercury monobromide molecules in $B^2\Sigma^+_{1/2}$ and $X^2\Sigma^+_{1/2}$ states due to dissociation of mercury dihalide molecules in collisions with electrons. The second excitation pulse (current), in addition, leads to an additional increase in the population the $B^2\Sigma^+_{1/2}$ –state of mercury monobromide molecules due to the process (19), where $HgX(X^2\Sigma^+_{1/2})$ mercury monoiodide and mercury monobromide molecules in the ground state and that did not have time to recover in triatomic molecules (mercury diiodide and mercury dibromide) in the interpulse period (150 ns) in the processes (13,14), which leads to an increase in the amplitude of the second radiation pulse and an increase in its duration compared to the first pulse.

Based on the calculated reaction rate constants (Fig.7) and specific power loss distribution (Fig.8) as a function of E/N, appears the possibility to assume the optimal power input scheme inorder to get the maximum possible emission from simultaneous violet - blue ($\lambda=444$ nm) and blue-green ($\lambda=502$ nm) spectral ranges for the HgI$_2$ / HgBr$_2$/Xe / Hemixture. Indeed, the excitation of the levels of the main reactions is attained at 11-30 Td (seeFig.8).

This field is too small for effective ionization of the mixture and stable development of the discharge. At pressures higher than 1 Atm, a much higherelectricfieldisrequired, atleast 100 Td. Thus, a mixed power source, when a short powerful pulse of a few nano seconds in duration (3-5) is used to obtain a relatively high initial ionization ($10^{12}$-$10^{13}$ cm$^{-3}$), and then a long pulse of ten hundreds of nano seconds, depending on the component composition of the mixture and pressure with relatively lowel ectric fields, provide effective excitation of HgI* and HgB * molecules, canbe the optimal solution for discharge lamps based on HgI* and HgBr* emission.

## 4. CONCLUSION

The simultaneous emission from two exciplex molecular bands HgI* ($\lambda=444$ nm) and HgBr* ($\lambda=502$ nm) in a nano second DBD in a mixture of HgI$_2$/HgBr$_2$/Xe/He = 0.001635/0.0005513/0.005514/ 0.9823 at atmosphere pressure is studied. Specific power radiation in a single pulse- 96 W/cm$^3$ and the average- 260 mW/cm$^3$ at a pulse repetition rate of 18 kHz is achieved. Long-term stable more than $7 \cdot 10^7$ pulses (within a measurement error of 10%) emission was detected.

The current and radiation shape of HgI* and HgBr* molecules with a temporal resolution are investigated. It is established that HgI* radiation repeats the form of HgBr* radiation and is close in the time scale.

Based on the analysis of possible reactions of excitation and quenching, it was found that the population of the exciplex molecules HgI* and HgBr* $(B^2\Sigma^+_{1/2})$-state takes place mainly due to dissociative excitation in collisions with electrons. A discussion of additional processes that increase the population of the upper $B^2\Sigma^+_{1/2}$- state of mercury monohalides is given.

As a result of calculating the reaction rates and energy distribution for different electric fields, it can be concluded that a combination of a high electric field at the front of the discharge and a low field over the duration of the pulse can be used to increase the emission power in the mixture studied.

Based on the results of plasma emission investigations of a barrier discharge in a mixture of mercury diiodide and mercury dibromide vapor with xenon and helium, an efficient source of simultaneous two-band emission in the violet-blue and blue-green spectral ranges can be created, which will be used as a source of active photosynthetic radiation and a laser in the field of biotechnology, photonics, medicine, etc.

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