

Conference Paper

Experimental Research of XeBr Excimer Molecule Luminescence in Ar-Xe- C₂HBrClF₃ Gas Mixture with High Energy Particles Excitation

A.V. PODKOPAEV^{2,3} and A.I. MIS'KEVICH^{1,3}

¹National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe shosse 31, Moscow, 115409, Russia

²Obninsk Institute for Nuclear Power Engineering of the National Research Nuclear University MEPhI, Studgorodok 1, Obninsk, Kaluga region, 249040, Russia

³Joint Stock Company "State Scientific Centre of the Russian Federation – Institute for Physics and Power Engineering named after A. I. Leypunsky"

Abstract

The results of experimental research of spectral and time-resolved properties of XeBr excimer molecule luminescence in high-pressure gas mixtures of Ar-Xe-C₂HBrClF₃ under fast electron ($E_e = 150$ keV) and uranium-235 fission fragment ($E_f = 100$ MeV) excitation are represented. For various gas mixture composition and pressure the luminescence spectrum in 200-1200 nm wavelength range and the fluorescence lifetime for B-X emission band of XeBr* ($\lambda_{\max} = 282$ nm) excimer molecule was measured and decay rate of that emission band by Fluothane molecules (C₂HBrClF₃) was determined. The quenching rate of XeBr* by Fluothane and fluorescence lifetime of XeBr* was found to be $6,3 \cdot 10^{-10}$ (cm³/s) and 125 ns respectively. For the gas mixture consisted of 760 Torr of Ar and 15 Torr of Xe the maximum luminescence output was achieved with partial pressure of C₂HBrClF₃ equal to 4 – 6 mTorr

Keywords: excimers, luminescence, nuclear pumping, bromine donors, decay rate

1. Introduction

Excimer molecules is a wide class of the compounds that include rare gas-halide molecules [1]. The XeBr* excimer molecule was the first excimer molecules for which laser generation was obtained [2]. Characteristics of the XeBr* emission on 282 nm wavelength allows to use it in many of the modern equipment with a great success. For example, the XeBr* excimer molecule emission is accepted to be most effective in the excimer lamps for removing organic impurities [3]. There is a big disadvantage that bromine and many of other compounds that used as the gas mixture compounds have

Corresponding Author:

A.I. MIS'KEVICH
miskev@mail.ru

Received: 28 January 2018

Accepted: 15 March 2018

Published: 25 April 2018

Publishing services provided by
Knowledge E

© A.V. PODKOPAEV and A.I. MIS'KEVICH. This article is distributed under the terms of the [Creative Commons](#)

[Attribution License](#), which permits unrestricted use and redistribution provided that the original author and source are credited.

Selection and Peer-review under the responsibility of the PhI0 Conference Committee.

 OPEN ACCESS

a great chemical activity [4]. Accordingly, the research of kinetic of the rare gas-halide excimer molecules and investigation for a new donor compounds is actual tasks.

The $C_2HBrClF_3$ molecule was used in research as the bromine donor for the $XeBr^*$ excimer molecule. This substance (halothane) is a liquid that have molecular weight of 197,381, boiling temperature of 50.2 °C and the vapor pressure of 243 Torr. The Halothane have a much less chemical activity in comparison with other materials used as donors of the Br atom. The number of experiments was occurred to investigate the ability of application of halothane and to estimate basic parameters of the halothane-based gas mixture luminescence.

2. Materials and methods

Two setups were used in experiments. The first one was meant for research of gas mixture luminescence under the e-beam excitation, and the next one for the uranium 235 fission fragment bombardment. The first setup [5] consist of a gas loop, accelerator part and registration system. The gas mixture of essential composition was created in the gas loop from gas balloons that contain necessary rare gases. This mixture gets an additional purification from impurities by multiplied passes through the filter that contain titanium sponge heated up to 700 °C. The necessary amount of halothane was added to the mixture from the halothane-containing capsule by using a gauge tube. The resultant mixture gets a continuous mixing by membrane pump. The mixture had been excited by e-beam from RADAN-220 accelerator. IMA-150E accelerating tube was placed in the chamber contained by investigated media. The e-beam with an energy by a mean of 150 keV excite the gas mixture during the pulse of the accelerator that have 5 ns wide. The start of accelerator was synchronized with the lite emission registration system. The chamber with size of 100x150 mm was made of stainless steel and had a silica windows on each side for the exit of light. The system of registration consists of Maya-2000 Pro spectrometer that have 0,5 nm/div resolution, MDR-23 monochromator, PMT-106 photomultiplier and the fast digital oscilloscope with the 2 ns/div time resolution.

The equipment that was a part of «Stand B» experimental statement for nuclear-pumped lasers researches was used for uranium fission fragment excitation od investigated gas mixtures [6]. It consists of fast aperiodic pulse reactor BARS-6 and the system of laser elements. The laser element in which experiments take plays is a tube of 250 sm length and 2,5 sm diameter, that have uranium oxide layer on its

inner wall. The sides of tube are mounted with optical windows for light emission. The light exit from the reactor room by the system of mirrors and then it is focused on measuring equipment. The Maya2000 Pro spectrometer, PMT-100 and PMT-106 photomultipliers connected with Tektronix1012 fast digital oscilloscope was used as a measuring equipment.

The gas loop has been evacuated to the pressure of 0.001 Torr before the work with RADAN-220 accelerator has begun. The gas mixture of Ar and Xe at the ratio of 760:15 Torr was made in the gas loop. Then the resultant mixture has been cleaned through the titanium filter. Concentration of impurities was monitored by the Maya2000 Pro spectrometer from its luminescence spectrum. The pumping through the titanium filter was over when intensity of impurity's spectral lines became lower. The halothane vaporous was added to gas mixture by the gauge tube, which was a part of gas loop. The gauge tube was calibrated by the volume and its volume have a ratio of 1:100 to the whole gas loop. Consequently, managing the pressure of vaporous in the tube with precision up to 0.01 Torr the halothane concentration was managed with precision up to 0,0001 Torr when it was added to the gas loop. Then the number of accelerator shots with variation of the halothane concentration in a range from 0.0005 to 1,6 Torr have been occurred. The data from spectrometer and oscilloscope have been recording to the PC memory as digital worksheets during these pulses. The worksheets from spectrometer contain the data about level of intensity of signal in the all channels from 200 to 1100 nm at a pitch of 0.5 nm. The worksheets from the oscilloscope contain the value of voltage on the photomultiplier output in the time range of 500 ns at a pitch of 2 ns.

For the fission fragment excitation experiments the laser element that had been previous evacuated for pressure of 0.05 Torr was filed with gas mixture of Ar-Xe-C₂HBrClF₃ with the partial pressure ratio of 760:15:0,05. Torr. The start of measurement equipment was synchronized with the start of reactor pulse. During the luminescence pulse, the data from spectrometer was recorded by a same way that has been described before and the data from oscilloscope was recorded in a time range of 1 ms at a pitch of 2 ns.

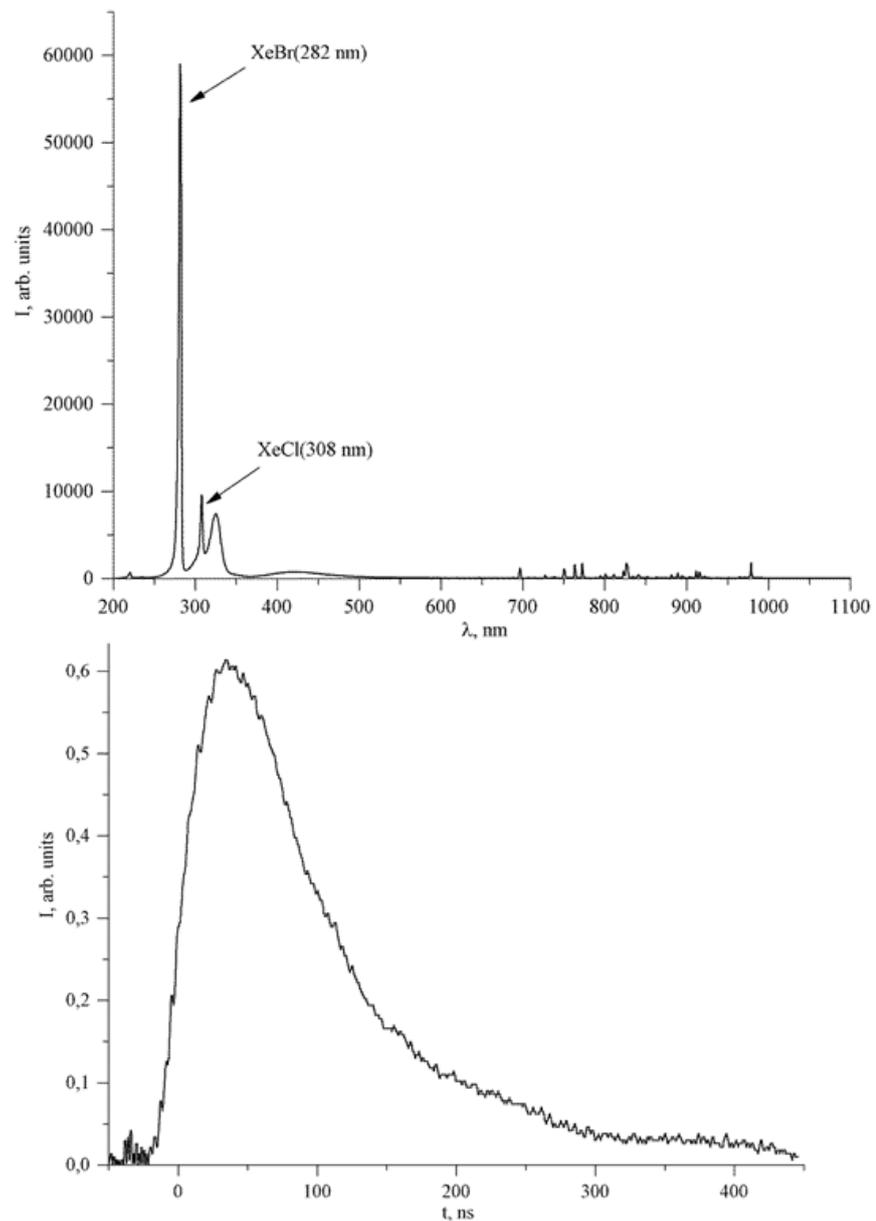


Figure 1: Luminescence spectrum (a) and time resolved dependency of luminescence intensity on 282 nm (b). The Ar-Xe-C₂HBrClF₃ gas mixture with a partial ratio of (760:15:0,005) excited by e-beam.

3. Results

The data about XeBr* luminescence under e-beam excitation and uranium fission fragment excitation of the Ar-Xe-C₂HBrClF₃ gas mixture was obtained. The data was classified and processed in PC by Origin 9.0 program. The background subtraction and averaging by a 5 measurements for a e-beam experiments was made during procession of data worksheets. Averaging was made by LS method and it have shown that

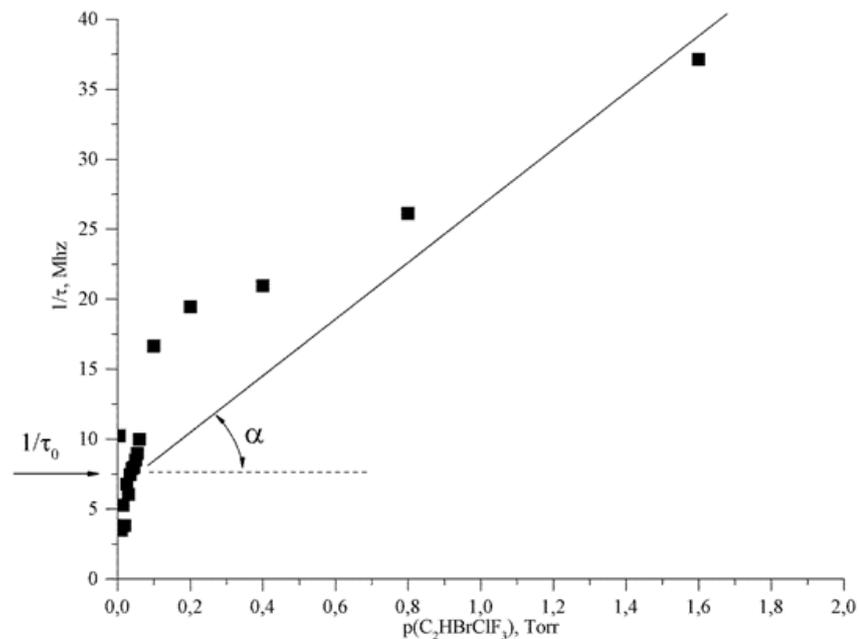


Figure 2: The decay rate to the $\text{C}_2\text{HBrClF}_3$ partial pressure dependency of XeBr^* excimer molecule. The Ar-Xe- $\text{C}_2\text{HBrClF}_3$ gas mixture with atmospheric pressure.

an error of spectrometer measurement was less than 6 % and 0,2 % at the mean. The error oscilloscope measurement was less than 10 % and 2 % at the mean.

The Luminescence spectrum of Ar-Xe- $\text{C}_2\text{HBrClF}_3$ gas mixture with the partial pressures ratio of 760:15:0,05 Torr under e-beam excitation is shown on the Figure 1a. The Figure 1b. demonstrate the time resolve dependency of luminescence intensity on the B-X transition ($\lambda_{\text{max}}=282$ nm) of XeBr^* excimer molecule that was generated in investigated gas mixture under e-beam excitation.

The dependency of light yield from halothane partial pressure was obtained by integrating of intensity of the XeBr^* B-X emission broadband ($\lambda_{\text{max}}=282$ nm) in gas mixtures with various halothane concentration. Optimal concentration of this type of bromine donor belong to the range from 0.04 to 0.06 Torr for the Ar-Xe- $\text{C}_2\text{HBrClF}_3$ with the ratio of Ar:Xe of 760:15 Torr. Than the curve form of emission $\text{Ln}(U)(t)$ was analyzed where U is voltage registered by oscilloscope and it was proportional to luminescence intensity on the XeBr^* excimer molecule B-X transition (282 nm). The line area was detected in the field of $\text{Ln}(U)$ reduction, the contrary time of gas mixture emission have been given by the slope of this line. The calculation of decay rate constant of XeBr^* excimer molecule by $\text{C}_2\text{HBrClF}_3$ molecule was made by plotting of the contrary time of emission against the halothane pressure (Figure 2). The line extrapolation of contrary time of emission to halothane concentration dependency was used to calculation. The slope of extrapolation line give the value of decay rate to be equal

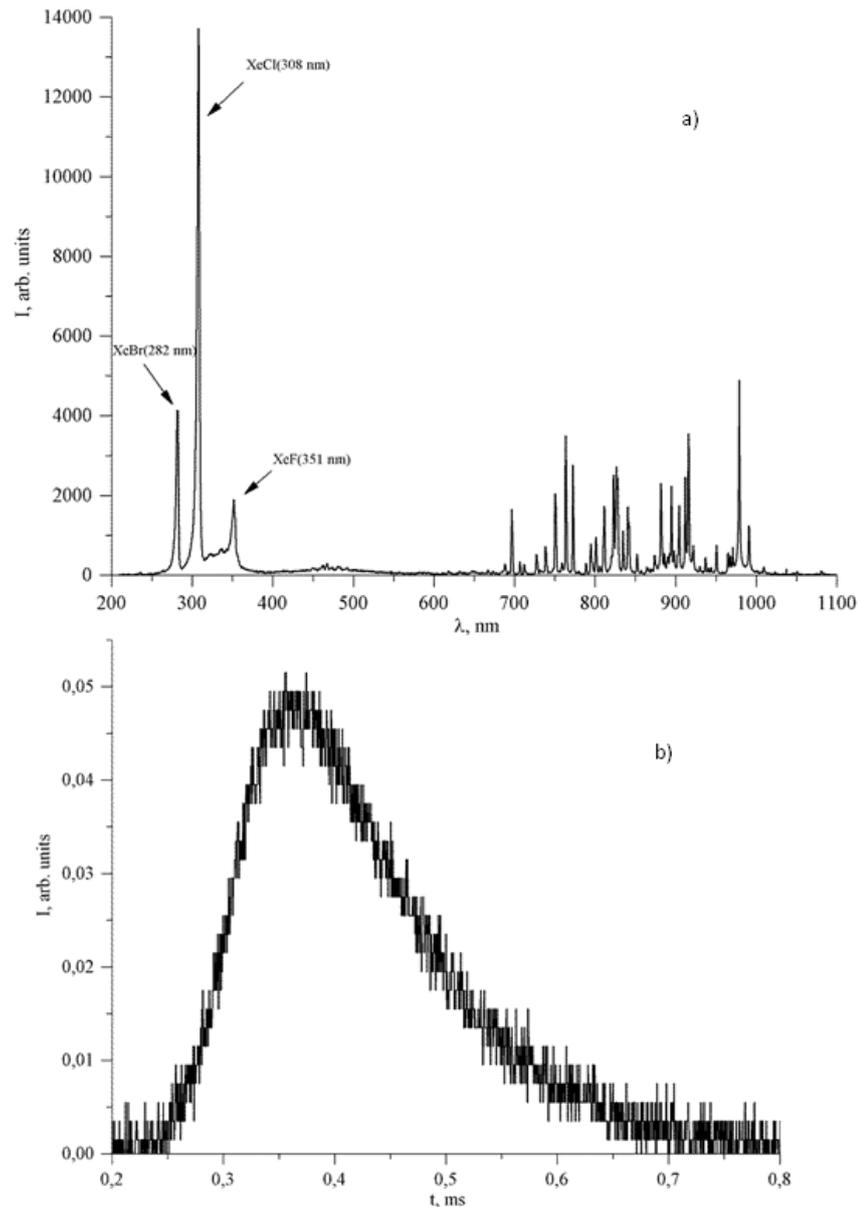


Figure 3: Luminescence spectrum (a) and time resolved dependency of luminescence intensity on 282 nm (b). The Ar-Xe-C₂HBrClF₃ gas mixture with a partial ratio of (760:15:0,005) excited by U₂₃₅ fission fragment.

to $6,3 \cdot 10^{-10} \pm 0,6 \cdot 10^{-10}$ (sm³/s). The value of emission time of XeBr* in investigated mixture of 125 ± 10 ns was given by interpolation of the extrapolated line to the point of zero halothane concentration.

The luminescence spectrums of Ar-Xe-C₂HBrClF₃ for a mixture with ratio of partial pressures of 760:15:0,05 Torr and the time resolved dependency of XeBr*B-X ($\lambda_{\max}=282$ nm) transition luminescence intensity was obtained in the experiment with uranium fission fragments and they are shown on the Figure 3 a. and b.

4. Discussion

The XeBr* excimer molecule luminescence parameters in new gas mixture based on halothane was obtained during the experimental work. Generally, the values of obtained parameters with halothane as a donor are comparable with another donor's parameters. For example, the Br₂ decay rate is about from 1×10^{-9} sm³/s [7] to 6×10^{-10} sm³/s [8] according to the different estimates. It is shows that the halothane quite usable as a donor of Br in works with XeBr* excimer molecule. Moreover, it was shown by the luminescence spectrum obtained during the excitation experiments that halothane can be also used as Cl and F donor and by this way UV sources of all three B-X transition emission of XeBr*, XeCl* and XeF* respectively can be received.

The following research of halothane as a Br donor will be focused on the laser generation on 282 nm line, also with nuclear pumping. However, the number of experiment must be produced to determine optimal compound of active laser media and resonator properties.

Acknowledgments

Authors would like to thank all the personal of the IPPE who working in reactor laser statement "Stend-B" for assistant in experiments with uranium fission fragment excitation and other personal of lab for help in mounting and adjustment of measurement equipment.

References

- [1] Golde M. F. Interpretation of the oscillatory spectra of the inert-gas halides //Journal of Molecular Spectroscopy. – 1975. – V. 58. – №. 2. – P. 261-273.
- [2] Searles S. K., Hart G. A. Stimulated emission at 281.8 nm from XeBr //Applied Physics Letters. – 1975. – V. 27. – №. 4. – P. 243-245.
- [3] Matafonova G., Batoev V. Recent progress on application of UV excilamps for degradation of organic pollutants and microbial inactivation //Chemosphere. – 2012. – V. 89. – №. 6. – P. 637-647.
- [4] Mizunami T., Takagi K. Buffer gas effect in a discharge-pumped XeBr excimer laser //Journal of applied physics. – 1992. – V. 71. – №. 4. – P. 2036-2038.

- [5] Mis'kevich A. I., Podkopaev A. V. An installation for studying luminescence excited by high-energy charged particles in dense xenon-containing gas mixtures with the possibility of regeneration and repeated use of xenon //Instruments and Experimental Techniques. – 2017. – V. 60. – №. 3. – P. 458-462.
- [6] D'yachenko P. P. et al. STEND B reactor laser complex //Atomnaya Ehnergiya. – 2000. – V. 88. – №. 5. – P. 337-342. Brau C. A. Excimer Lasers, ed. CK Rhodes //Topics Appl. Phys. – 1979. – V. 30.
- [7] Shuaibov A. IC, Shevera, VS, " Formationof inert gas fluorides in an ac discharge //Sov. Phys. Tech. Phys. – 1980. – V. 24. – №. 8. – P. 976