INFLUENCE OF EXCITATION PULSE FORM ON BARRIER DISCHARGE EXCILAMP EFFICIENCY

M. I. Lomaev, V. F. Tarasenko, D. V. Shitz, V. S. Skakun

High Current Electronics Institute, 4, Akademichesky Ave., Tomsk 634055, Russia;
lomaev@loi.hcei.tsc.ru; VFT@loi.hcei.tsc.ru.

ABSTRACT

At present time, excilamps excited by a barrier discharge are the simplest and perspective as the sources of UV and VUV radiation. Influence of pulsed repetition rate of excitation of different temporal mode on the type of formed discharge, as well as efficiency and output parameters of Xe-Cl_2 barrier discharge excilamp were studied. It has been found that at pulsed repetition rate of about 1 kHz and higher there are brightly glowing microdischarges – filaments observed in the discharge plasma. The greater values of average radiation power and efficiency were achieved, correspondingly, 100 W and 13 %. The highest values of specific radiation power were obtained at excitation of the excilamp by voltage pulses of different polarity at maximum pulsed repetition rate (p.r.r) of 100 kHz, and made, depending on operating conditions of excilamp, up to 120 mW/cm^3.

INTRODUCTION

Study of spontaneous radiation sources based on exciplex and excimer molecules (excilamps) have received much attention owing to wide spectrum of their practical application [1-12]. The main distinctive feature of these sources is radiation spectrum. It basically consists of a relatively narrow (depending on the discharge type, from units to tens of nanometers at FWHM) band of B-X transition of the corresponding molecule. The most important parameters of radiation source are efficiency, specific radiation power, radiation spectrum and its stability, as well as the operation lifetime. In the previous papers [11,12] the influence of excitation pulse form on operating efficiency of excilamp was studied experimentally. The present paper is a continuation of [11,12] being devoted to influence of excitation mode (form, pulsed repetition rate of excitation), mixture pressure on character of the forming discharge, as well as the output parameters of Xe-Cl_2, Kr-Cl_2 barrier discharge excilamps.

EXPERIMENTAL SETUP

In the experiments, traditionally constructed water-cooled coaxial barrier discharge lamps made of quartz were used. Gas gap was 8÷10 mm, excilamp length was varied from 47 to 60 cm. Radiation power was determined by calibrated photoreceiver FEK-22 SPU. Excitation power was determined by two methods, using well-known method of volt-coulomb loops and by determining voltage at gas discharge gap taking into account voltage drop at the lamp capacity. In the second case there was a possibility to determine an instantaneous power value and deposited excitation energy for the instant moment of time. Two generators were used for excitation, one of those provided obtain of bipolar voltage pulses with duration at the base about 2 μs, at p.r.r. 100 kHz, and the second one provided unipolar voltage pulses with duration of leading and edge fronts of about 250 ns or about 1 μs at p.r.r.10 Hz ÷ 200 kHz. Registering of current pulses, voltage, and also time behavior of radiation pulses were realized using, correspondingly, current shunt, voltage divider, FEK-22 and oscilloscope TDS-220. In a number of cases, for the lamp volume voltage fall determining, into the circuit an additional capacity was installed in series, the signal from which was registered by the oscilloscope TDS-220 too. The integral picture of the discharge lighting was photographed using a digital camera.

INFLUENCE OF MIXTURE PRESSURE

As is well known, physical configuration of the barrier discharge (discharge form) depends on a row of factors, and the discharge may be uniform or particularly non-uniform. In the second case, in the discharge volume current channels present stochastically appearing for a short time (up to tens of nanoseconds), i.e. microdischarges, also named as filaments. At the uniform combustion of the discharge, the filaments are absent, that provides uniform excitation of operating mixture, whereas at their presence, the volume occupied by filaments is predominantly excited. In the conditions of conducted experiment, the uniform discharge took place at total

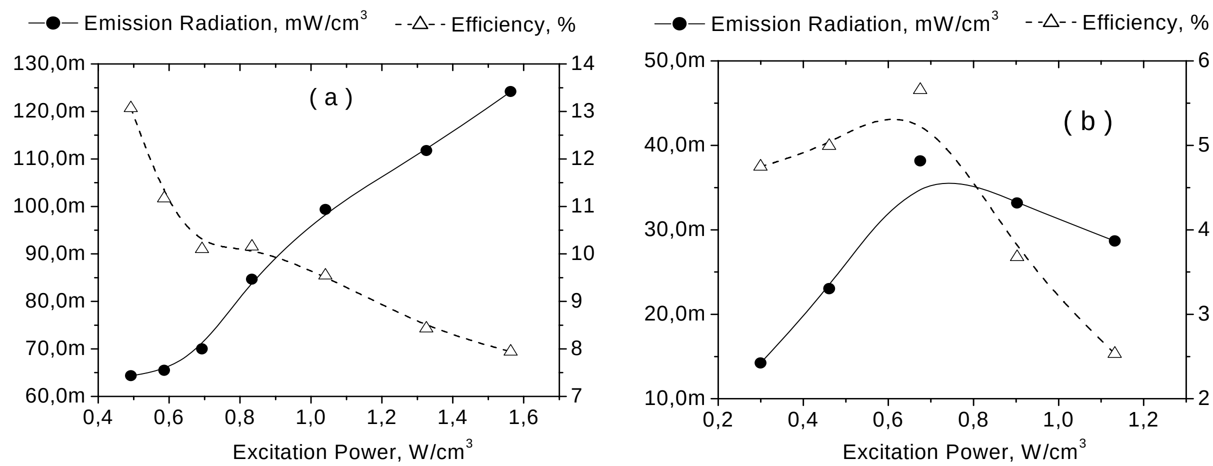

Fig. 1. Efficiency and specific emission radiation versus specific excitation power at Xe pressure of 120 Torr (*a*), 60 Torr (*b*) in mixture : Xe + 1 Torr Cl_2.

pressure of Xe-Cl_2 mixture not higher than ~ 60 Torr, and with optimal pressure from the point of view of radiation power of ~ 120 Torr the discharge with well-expressed filaments was formed. In Fig. 1*a -b*, the dependencies of efficiency and specific radiation power on the specific power of excitation at various pressure of Xe in mixture Xe – 1 Torr Cl_2 are presented. As it is seen from the Fig. 1, the highest values of radiation power (up to 120 mW/cm^3) and efficiencies (up to 13 %) are observed at pressure of 120 Torr. It is worth to note the presence of the radiation pulse time delay relatively the excitation pulse at the pressure of 60 Torr. The pressure influences both the total externals view of the discharge and on the parameters of a single filament, i.e., sizes of the foot, brightness of glowing. It has appeared, that along with increase of pressure from 90 Torr, when filaments occupy only a part of gas discharge volume, up to 150 Torr, i.e., the pressure value exceeding optimal one, an increase of both foot sizes and brightness of glowing of the filament on the whole occurs.

INFLUENCE OF FREQUENCY OF EXCITATION PULSES

One of the factors influencing on formation

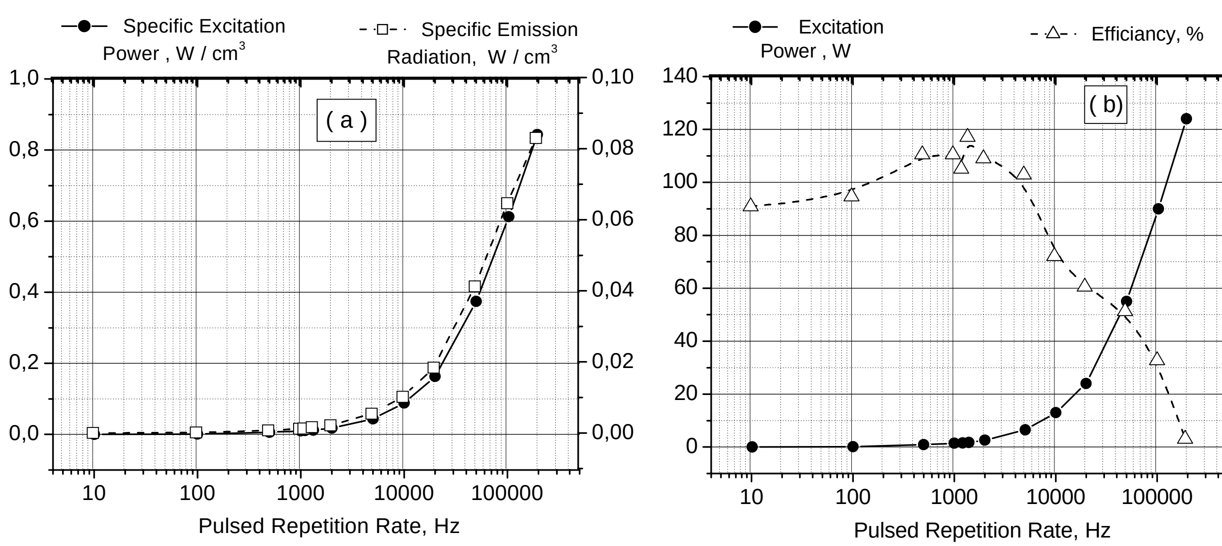

Fig. 2. Specific excitation power and emission radiation (*a*), excitation power and efficiency (*b*) versus pulsed repetition rate of Xe – Cl_2 barrier discharge excilamp.

conditions of a single filament, a discharge on the whole, efficiency and radiation power of excilamp is the time interval between the previous and the next pulses of excitation, i.e. p.r.r. With the aim to reveal the influence of that factor, we varied p.r.r. of unipolar pulses at excitation of $Xe\text{-}Cl_2$ excilamp from 10 Hz up to 200 kHz. The well-distinguished filaments were observed to appear in the discharge plasma at p.r.r. of excitation $\nu_0 \sim 1$ kHz. At $\nu < \nu_0$, in the gas discharge plasma, chaotically distributed by volume diffuse current channels with a relatively low glowing brightness are observed. At $\nu \geq \nu_0$, with ν increase, the density of filaments, foot sizes, and their brightness increase too. With this, the excitation power and, correspondingly, the radiation power increase as well. Change in external view, filament density, the separate filament glowing intensity, and, correspondingly, change in specific power of excitation at ν variation can influence on efficiency of excilamp operation. In Fig. 2, the dependencies of excitation power, radiation and efficiencies on ν for the $Xe - Cl_2$ excilamp are presented.

The principal change for the range $\nu \geq \nu_0$ relatively to $\nu < \nu_0$ is the formation of brightly glowing current channels with cone-shaped foot on the surface of dielectric. With this, the current density increases sharply, and, correspondingly, the specific power of excitation in the current channel of filament-sausage increases too, that may be the reason for decrease in efficiency with increase of ν, or excitation power at constant value of ν. Variation of p.r.r. results in volt-ampere characteristics change. In Fig. 3, the oscilloscope traces of current, voltage, radiation power, calculated curves of voltage at the gas discharge gap, voltage drop, power and excitation energy with ν = 10 (*a*) and 200 kHz (*b*) are presented. The Fig. 3 gives evidence that the values of breakdown voltages, current amplitudes and excitation powers are essentially different; the same is with the value of energy deposited into gas discharge

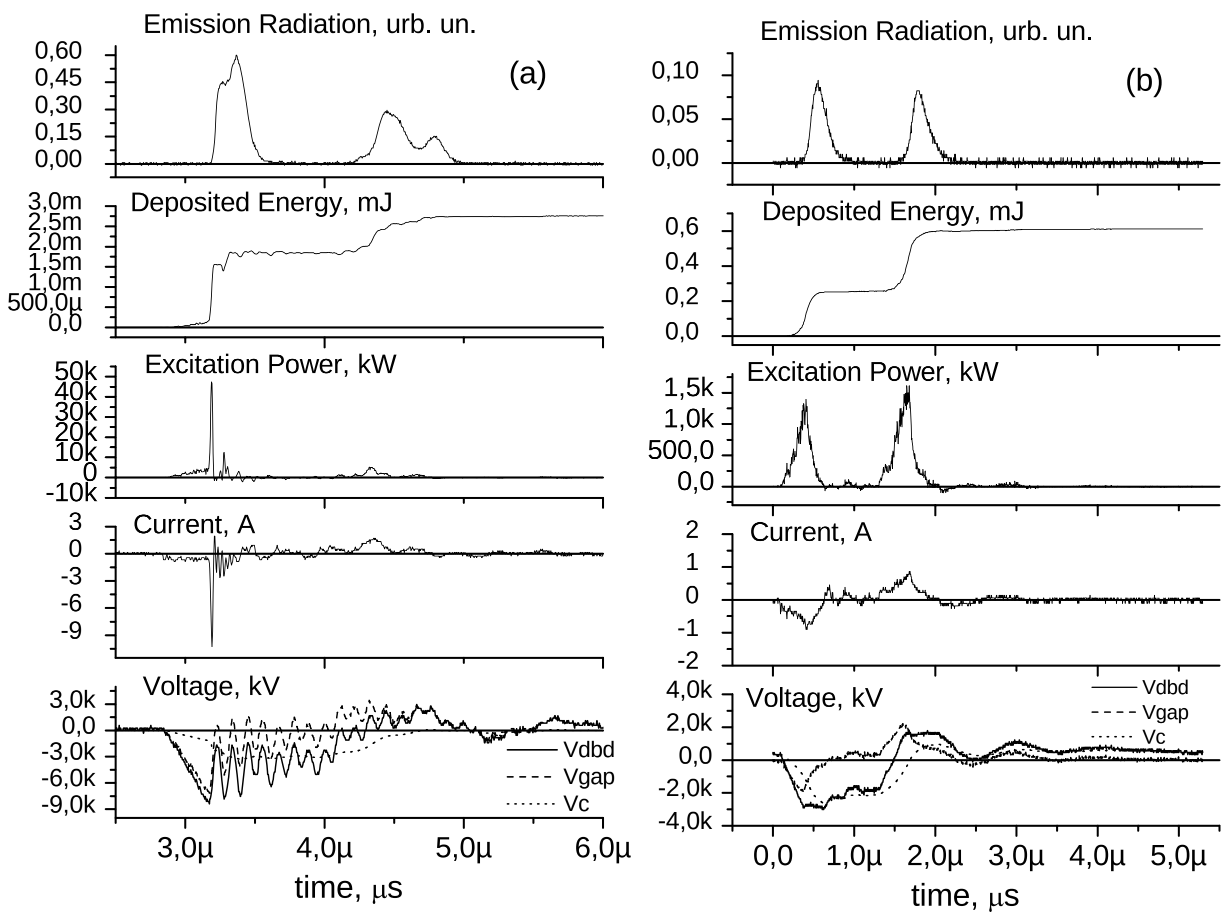

Fig. 3. Oscilloscope traces of UV radiation intensity, total current, excilamp electrodes voltage *V*dbd, calculated curves of gas discharge gap voltage *V*gap, capacity voltage *V*c, power excitation and deposited energy at pulsed repetition rate of 10 Hz (*a*) and 200 kHz (*b*).

plasma within one period. Thus, the energy input within one period for ν = 10 Hz is ~ 3 mJ, and for ν = 200 kHz ~ 0,6 mJ.

SEALED-OFF Kr-Cl_2 BARRIER DISCHARGE EXCILAMP

Based on the experienced findings on optimal pumping conditions a coaxial sealed-off KrCl-excilamp excited by a barrier discharge has been made. Excilamps sizes are as follows: length is 60 cm, external diameter is 65 mm, and gas discharge gap space is 10 mm. The internal tube of excilamp is water-cooled, and the external tube of the excilamp is air-cooled. In order to have not less than 100 hours lifetime for the excilamp, it was annealed and passivated by chlorine in muffle furnace. A power supply source for the barrier discharge excilamp with average power of up to 1,5 kW and repetition of bipolar pulses 100 kHz has been designed and manufactured. Study of radiation parameters and lifetime period of the manufactured excilamp has been performed. Average power of radiation for the just sealed off excilamp exceeded 115 W. Along with operating time, radiation power decreased a bit. Nevertheless, within 100 hours operation, decrease in output radiation power was merely 10 %. Decrease in radiation power during operation may be diminished using more intensive cooling.

CONCLUSION

The performed work has resulted in determination of dependencies of discharge burning, efficiency and radiation power of Xe–Cl_2 barrier discharge excilamp on mixture pressure and excitation pulsed repetition rate. A sealed-off Kr–Cl_2 excilamp with power of about 100 W has been manufactured. After 100 hours excilamp lifetime the decay of its radiation power was about ~ 10 %.

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