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HIGH POWER UV AND VUV PULSED EXCILAMPS

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Abstract. Emission characteristics of a nanosecond discharge in inert gases and its halogenides without preionization of the gap from an auxiliary source have been investigated. A volume discharge, initiated by an avalanche electron beam (VDIAEB) was realized at pressures up to 12 atm. In xenon at pressure of 1.2 atm, the energy of spontaneous radiation in the full solid angle was $\sim$ 45 mJ/cm^3, and the FWHM of a radiation pulse was $\sim$ 110 ns. The spontaneous radiation power rise in xenon was observed at pressures up to 12 atm. Pulsed radiant exitance of inert gases halogenides excited by VDIAEB was $\sim$ 4.5 kW/cm^2 at efficiency up to 5.5 %.

1. INTRODUCTION

Today the sources of spontaneous radiation developed on the basis of nonequilibrium emission of excimer molecules in UV and VUV spectrum – excilamps attract attention of many researchers and find wide application in various fields of research and engineering (Gellert and Kogelschatz 1991, Lomaev et al. 2003, 2006, Zhu et al. 2007). Most often, electrodeless barrier or capacitive discharges are used for excitation of excilamps (Gellert and Kogelschatz 1991, Lomaev et al. 2003, 2006). In this case it is possible to reach at pulse repetition rate of excitation $\sim$ tens-hundreds kHz the radiant power of $\sim$ 100 W and greater with the radiant flux about 100 mW/cm^2. However, in a number of applications there is a need to have a spontaneous UV or VUV radiation with the greater pulse power. For that one could use the volume pulse high current discharges in inert gases at high pressures, and inert gas mixtures with halogens.

This paper reports on the pulse sources of spontaneous UV and VUV radiation with the power up to 8 MW, developed on the basis of volume pulse high-current discharges at high specific power of excitation ($\sim$100 MW/cm^3) and pressures (up to 12 atm) in inert gases and its halogenides excited by high voltage generators of nanosecond pulses.

2. THE EXPERIMENTAL SET-UPS AND TECHNIQUES

In the experiments we used three set-ups. First set-up, forming a volume discharge without preionization, included a primary capacitive store, a pulse transformer, a coaxial line with a wave impedance of 10 Ω, a peaking discharger and gas diode. This developed set-up presents by itself a source of optical pumping with emitting area of a radiator of greater than 20 cm^2. The duration of a generator voltage pulse at a matched load is ∼ 50 ns. For study of discharge in inert gas halogenides (XeCl, KrCl, XeBr and KrBr) we used discharge chamber shown on Fig. 1 (set-up #2). Inner diameter was 36 mm. The discharge ignited between plane brass anode 1 (which was connected with ground through current shunt 3) and tube cathode 2, which was made from steel foil. The distance between electrodes was 5-12 mm. High voltage pulse with leading front width of ∼0.5 ns had amplitude ∼150 kV and ∼1.5 ns FWHM applied from RADAN-150 to cathode through isolator 5. A voltage pulse in case of RADAN-220 generator had a leading front width ∼0.5 ns, amplitude ∼220 kV and ∼2 ns FWHM. Pulse repetition rate was 1 Hz. For registration of the voltage on discharge gap we used capacitive voltage divider 6. FEK-22 SPU photocathode and Tektronix TDS-6604 (6 GHz, 20 Gs/s) were used for light registration. Radiation spectrum registered by StellarNet EPP2000-C25 spectrometer and vacuum monochromator VM-502.

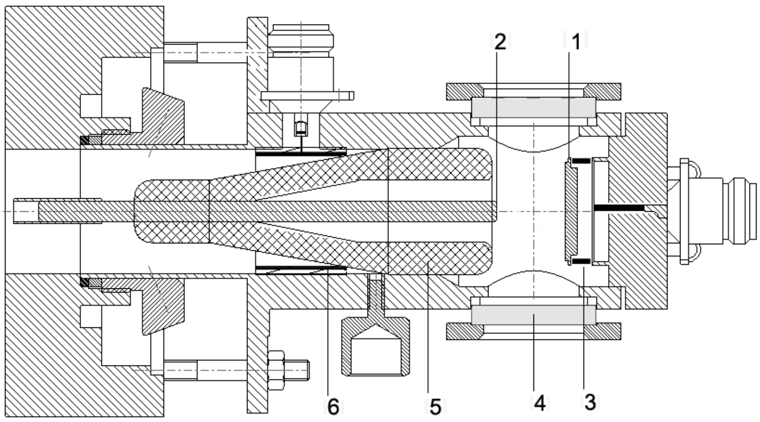

Figure 1: Discharge chamber. 1 – anode, 2 – cathode, 3 – current shunt, 4 – quartz window, 5 – insulator, 6 – capacitive divider of voltage.

3. RESULTS AND DISCUSSION

3.1. *Volume discharge in inert gases.* The discharge shape in Xe obtained on set-up #1 was like a truncated cone with a base on the anode. The diameter of the emitting area of the near-cathode discharge plasma was ∼ 6 cm, and ∼ 8 cm near the grid anode; the interelectrode distance was 4.5 cm. The maximum radiating power on Xe_2^* dimmers at 140-200 nm to the full spatial angle was obtained at the pressure of Xe of 760 Torr amounting ∼8 MW. The radiation pulse FWHM was of no greater than ∼100 ns, and the radiant exitance at excitation pulse duration of tens ns was $\sim 2\times 10^4$ W/cm^2. The investigations shows that the Xe dimers radiant power obtained on set-up #1 increases with the pressure growth of Xe until the value of 1 atm.

The characteristics of radiant emittance of the volume high-current discharge plasma in inert gases at pressure greater than 1 atm was investigated by using a RADAN-220 generator (Zagulov et al. 1989) with the voltage pulse amplitude of 220 kV and pulse duration at a matched load of $\sim$ 2 ns. The width of the pulse leading edge was $\sim$0.5 ns. A flat anode and a cathode with a small-curvature radius provided the electric field gain in the near-cathode region. Interelectrode distance ranged as 4 - 16 mm. The most homogeneous discharge was obtained in the high-pressure He. Fig. 2 shows an image of such a discharge. The subnanosecond electron beam of fast electrons was registered in He at the pressure of 12 atm. The beam current pulse duration at a half-height was no greater than 100 ps.

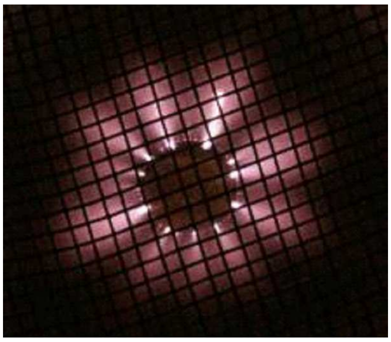

Figure 2: A photograph of a discharge in He at the pressure of 12 atm.

At Xe pressures greater than 3-4 atm there were observed the discharge contraction channels. At the same time, the high-power radiation of Xe dimer band was recorded at the pressures less than 12 atm. The duration $\tau_{1/2}$ at FWHM and power P of VUV radiation pulse as functions of Xe pressure are presented on Fig. 3. It is seen, that the value of P increases at pressures up to 12 atm meanwhile radiation energy decreasing. The maximal value of $P \sim 1$ MW and the shortest $\tau_{1/2} \sim 8$ ns was obtained at pressure 12 atm.

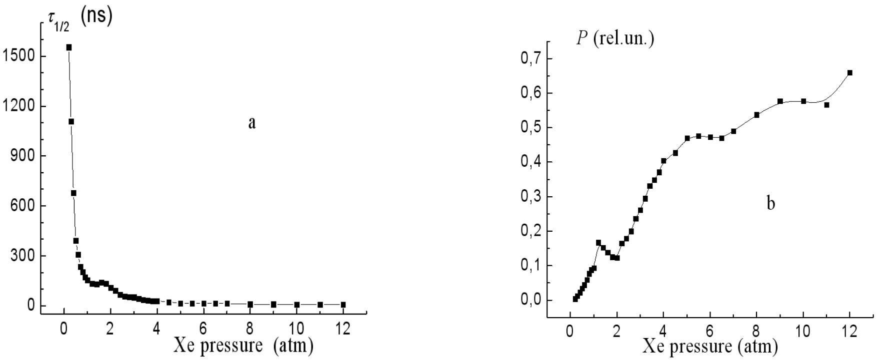

Figure 3: The duration (a) and power (b) of VUV radiation of Xe dimers vs Xe pressure.

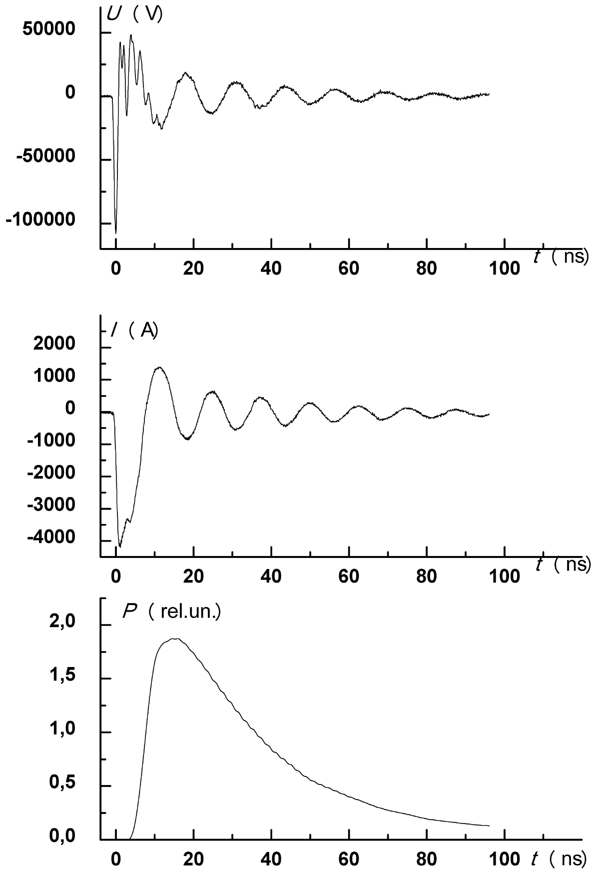

Figure 4: Typical oscilloscope traces of voltage pulse, discharge current and light pulse of volume discharge in Xe/Br_2=50/1 working mixture at 500 Torr.

3.2 *Radiation of inert gas halogenides.* Investigations of radiation of inert gas halogenides excited by high voltage generator RADAN-150 (set-up #2) was carried out in the operating mixtures pressure range of 60–750 Torr at various inert gas/halogen. Peak power of volume discharge radiation increases with increasing gap between electrodes. At low pressure (60–120 Torr) and discharge gap of 12 mm discharge had diffuse radiated cone-like form. With increasing of pressure discharge obtained form of the diffuse canal with diameter ~3 mm which contracted at the pressure of 500 Torr and than became in a spark. Increasing of halogen concentration in an operating mixture leads to the discharge contration at lower pressures and to the decreasing of radiant power. The optimal values of working pressures for the working gas mixtures Kr/Cl_2, Xe/Cl_2, Xe/Br_2 are 500 Torr at the ratio inert gas/halogen = 50/1. For Kr/Br_2 the working pressure was 750 Torr at Kr/Br_2 = 100:1. The highest pulsed power densities of $KrCl^*$, $XeCl^*$, $XeBr^*$, and $KrBr^*$ molecules radiation were 3.7 kW/cm^2, 3.1 kW/cm^2, 4.5 kW/cm^2, and 2.1 kW/cm^2 at the efficiencies 5%, 4.8%, 5.5%, and 4%, respectively. At this conditions input energy to discharge plasma was ~1 J.

Oscillograms of voltage pulse, discharge current and light pulse of volume discharge in Xe/Br_2=50/1 working mixture at 500 Torr are shown in Fig. 4. Pulse of the current was recorded at the front of the voltage pulse and had short delay (< 1 ns) relative to the voltage pulse. There was no prebreakdown peak at the voltage pulse which amplitude usually higher than voltage of quasi-steady phase of volume discharge with intense preionization. Similar oscillograms was obtained in (Kostyrya 2004) where such mode of discharge has been named volume discharge initiated by an avalanche electron beam (VDIAEB).

Pulse duration of volume discharge radiation in inert gas halogenides was 30-40 ns at FWHM. The radiation spectra of pulse XeCl-, KrCl-, XeBr-excilamps consist of narrow intensive bands of B–X transitions and weak-intensive bands of D–A and C–A transitions. The radiation spectrum of the pulse KrBr-excilamp consists of bands of B–X transitions of KrBr* (206 nm) and Br^*_2 (289 nm) molecules, and bands of C–A (222 nm) and B–A (228 nm) transitions of KrBr* molecule. The ratios of band intensities of transitions of KrBr* and Br^*_2 molecules change depending on the content of Br_2 in a working mixture – the more Br_2 portion, the less intensive bands of B–X, C–A and B–A transitions of KrBr* molecule are.

4. CONCLUSION

A volume discharge in helium, initiated by an avalanche electron beam, was realized at pressures up to 12 atm. In xenon with pulser RADAN-220 at pressure of 1.2 atm, the energy of spontaneous radiation in the full solid angle was $\sim$ 45 mJ/cm^3, and the FWHM of a radiation pulse was $\sim$ 110 ns. The power of $\sim$1 MW /cm^3 at duration of $\sim$ 8 ns of Xe dimer radiation was obtained at pressure of 12 atm. The maximum radiant power on Xe_2^* dimmers to the full spatial angle was obtained with set-up #1 was $\sim$8 MW. In this report the opportunity of generation of volume pulsed discharges in inert gas halogenides without preionization is also shown. The highest pulsed power densities of KrCl*, XeCl*, XeBr*, and KrBr* molecules radiation were 3.7 kW/cm^2, 3.1 kW/cm^2, 4.5 kW/cm^2, and 2.1 kW/cm^2 at the efficiencies 5%, 4.8%, 5.5%, and 4%, respectively. In the optimal conditions, radiation pulse duration at a half-height was 30 – 40 ns. The radiation spectra of KrCl-, XeCl-, XeBr-excilamps possessing the high-pulsed power density consist of the narrow intensive bands of several nm at a half-height of B–X transitions of the respective molecules.

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