Xe(He)–I_2 GLOW AND CAPACITIVE DISCHARGE EXCILAMPS

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ABSTRACT

In the present paper, Xe–I_2 and He - I_2 glow and capacitive discharge excilamps have been studied. These excilamps emit at iodine monatomic resonance lines in the range of 180 – 210 nm, and on XeI^* molecule band (λ_{max} = 253 nm). Besides that, by varying pressure and mixture composition, it is possible to control relation between iodine monatomic lines and XeI^* molecule band radiation intensity. The efficiency level is up to 10 %. The lifetime in sealed-off and quasi-sealed-off modes is up to 1000 h.

Keywords: Iodine, capacitive and glow discharge, excilamp

1. INTRODUCTION

Nowadays an active interest has been expressed in creation of efficient mercury free gas discharge sources of spontaneous radiation in UV and VUV spectrum ranges [1,2]. For the most part the papers of this direction are devoted to study more efficient Xe excilamps radiating in the main at B-X transition of X_2^* dimer (λ = 172 nm) [3-5 and others]. Nevertheless, in a row of applied problems radiation at the range of 180 – 210 nm is demanded which may be obtained using iodine excilamp operating on iodine vapours or mixture of iodine with inert gases [6-9]. In the radiation spectrum of such lamps at low pressure the lines of iodine atomic transitions at λ = 183, 185, 206 nm; and at high pressure the bands of molecule I_2 (λ = 342 nm) and corresponding exciplex molecules are dominating. In the case of using Xe – I_2 mixture the most intensive B-X band of the molecule XeI^* (λ = 253 nm) coincides with the resonance line of mercury atom that is rather promising from the point of view of mercury free luminescent lamps creation.
One of the main problems at creation of low-pressure iodine lamps taking into account its practical use is a relatively low level of the specific power radiated. It is known that radiation of resonance lines is mostly efficient at low pressure and relatively low excitation power [10]. Several known types of low pressure discharges, i.e. glow, capacitive, inductance and other discharges comply with these requirements. It was found [11-12] that using the mixtures Xe–I_2, He–I_2 or Xe– He–I_2 instead of iodine vapour or mixture Ar(Ne)–I_2 it is possible to obtain higher radiation efficiency of the low-pressure glow and capacitive discharge excilamps.
The present work is devoted to further investigation of Xe(He)–I_2 excilamps excited by glow and capacitive low-pressure discharges.

2. EXPERIMENTAL SET-UP AND METHODS

The experiments were conducted with the excilamps of cylindrical construction made of quartz with transmissivity at λ = 200 nm not less than 70%. In a row of cases in order to increase the operating lifetime a special box with iodine in a solid phase connected to the discharge volume was used. The temperature of the box as the most cool zone of the lamp determines the concentration of iodine vapours in the operating mixture. In Figs 1 and 2 the constructions of glow discharge and capacitive discharge excilamps are presented. Electrodes, bulb walls, discharge zone, and the box with crystalline iodine are shown by numericals 1, 2, 3, and 4, correspondingly. The Fig. 1*a,b* depict constructions of the glow discharge excilamps, correspondingly, in zones behind electrodes and in the middle part of the bulb. The Fig. 2 shows the capacitive discharge excilamps.
For excitation there were used high voltage generators with pulse repetition rates from 10 to 100 kHz for the capacitive discharge excilamps, and the set step-up transformer providing alternating and rectified voltage for the glow discharge excilamps. Power of excitation for the capacitive discharge lamps was determined by two methods, using well-known method of volt-coulomb figures [13,14] and by determining voltage at gas discharge gap taking into account voltage fall

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at 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. For the glow discharge excilamps, current and voltage integrating determined the power of excitation. Registering of current pulses, voltage, and also time behaviour of radiation pulses were realised using, correspondingly, current shunt, voltage divider, FEK-22 and oscilloscope TDS-220. Measurements of radiation intensity in the needed spectral range were made using calibrated photodiode FEK-22 SPU and set of light-filters with definite transmitting coefficients at different spectral ranges using known method [15]. Besides that, the radiation spectrum of the lamp in the range of 200 ÷ 600 nm using special spectral complex including monochromator MDR-23, FEU-100, constant current amplifier U5-11, and plotting device N-307 was measured.

3. EXPERIMENTAL RESULTS and DISCUSSION

In the work radiation intensities in the range 200 nm < λ < 255 nm for operating glow discharge and capacitive discharge excilamps with operating mixtures Xe - I_2, He - I_2 , He - Xe - I_2 at equal partial pressures of He and Xe, Ar - I_2 and I_2 were estimated. The pressure of the active media of the glow discharge excilamp t which the maximum radiation power level was provided was typical for a glow discharge [16] and made ~ 0.1 ÷ 20Torr. Pressure increase resulted in decreasing of radiation power and worse discharge operating due to contracting occurs. Low pressures as < 0.1 Torr were also non-optimal. First, it occurred due to radiation power decrease. Second, at low-pressure cathode material sputtering and metal electrode iodide production rate increase resulting in undesirable decrease of the tube transparency. The data obtained on radiation power of excilamp for different operating mixtures in Table 1 are presented. Excitation was performed at equal pressures of buffer gas and iodine vapours (the temperature of the box, the most cool bulb zone of the excilamp with crystal iodine did not changed), and at equal voltage to the lamp's electrodes from the supply source.

Table 1.

Operating mixture	Xe - I_2	He - I_2	He-Xe-I_2	Ar - I_2
Radiation power, arb. un.	1	0.9	0.85	0.1

It is seen from the Table 1 that the most high values of the radiation power take place for the operating media Xe - I_2, He - I_2, He - Xe - I_2. Radiation efficiency made there not less than ~ 12 %. Dependencies of the glow discharge excilamp efficiency and output power on excitation power for the operating media Xe - I_2, He - I_2 are presented in Fig. 3*a,b*. When using operating medium Ar - I_2 or iodine vapours only the lamp operation is much worse. Efficiency value with this did not exceed ~ 2 ÷ 4 %. The lifetime of the sealed-off glow discharge excilamp with operating mixture Xe - I_2 made more than 1000 hours. When needed the box could be heat-isolated or warmed, either at the expense of the part of the discharge current flowing to special electrode placed in the box. Current was reduced with use of a resistor placed between the spiral and one of the main electrodes.

The similar results have been obtained for the capacitive discharge excilamps. In Figs. 4,5 oscilloscope traces of voltage pulses, current, radiation pulses, and also excitation power calculation curve and voltage on discharge gap curve are presented. In the current work performance radiation intensities in the range 200 < λ < 255 nm at filling-in the lamp with operating mixtures Ne - I_2, Kr - I_2, Xe - I_2, He - I_2 and He - Xe - I_2 at equal partial pressures of He and Xe, and also in the mixture Ar - I_2 and iodine vapours were defined. The optimum pressure of operating mixture at which the maximum power level of UV was provided depends on pulsed repetition rate and it did not exceed 15 Torr for the frequency 20 kHz, with this use of more heavy buffer gases decreased the optimum pressure. In Table 2 the data obtained on lamp radiation power determination for different operating mixtures are presented. The excitation was realised at equal pressures of the buffer gas and iodine vapours, and also at equal voltage applied to the lamp electrodes from the supply source at 20 kHz frequency. It is seen from the Table 2 that the most high radiation power values take place when using operating mixtures such as He - I_2 , Xe - I_2, He - Xe - I_2. The radiation efficiency was not less than ~ 9 %. At use of Ar - I_2 operating mixture the lamp's operation was much worse. Value of efficiency did not exceed ~ 1 %. Excitation of only iodine vapours without addition of buffer gas with listed conditions on supply and geometry demanded preliminary lamp warming up and gave more less radiation powers.

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Table 2.

Operating mixture	$Xe-I_2$	$He-I_2$	$He-Xe-I_2$	$Ne-I_2$	$Ar-I_2$
Radiation power, arb. un.	0.9	1	0.7	0.4	0.1

Radiation spectrum of the capacitive discharge excilamp in the operating mixture $Xe-I_2$ at pressure of Xe ≅1 Torr is presented in Fig. 6. It is seen that at this mixture pressure the atomic iodine line λ = 206.2 nm dominates in the spectrum. At pressure rise up to 10 Torr and more the radiation spectrum contains not only the line λ = 206.2 nm but also the band λ = 253 nm of the molecule XeI^* increasing with the mixture pressure rise.
The lifetime of the sealed-off excilamp pumped by a capacitive discharge with the operating mixture Xe - I_2 made more than 1000 hours.

4. CONCLUSION

The study of $Xe–I_2$ and He - I_2 glow and capacitive discharge excilamps was performed. The efficiency up to 12 % and lifetime in sealed-off and quasi-sealed-off modes up to 1000 h were demonstrated. These results can be utilised in developing and use of effective lamps based on glow and high-frequency capacitive discharges radiating in vacuum ultraviolet and ultraviolet ranges of wavelengths.

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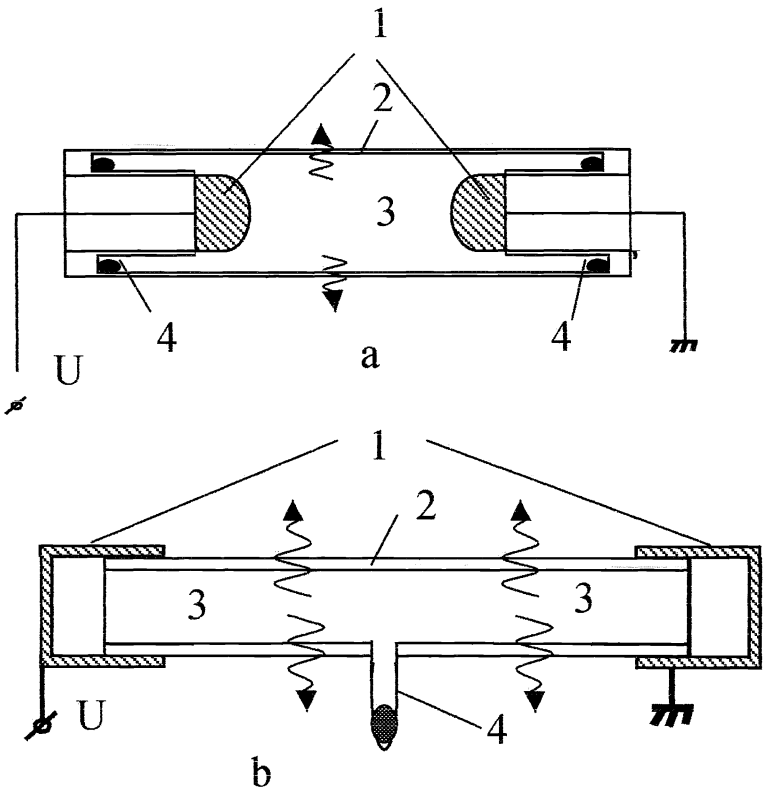


Fig. 1. Design of glow discharge excilamps : 1- electrodes, 2- quartz bulb 3 – gas-vapour mixture, 4 – iodine in solid state.

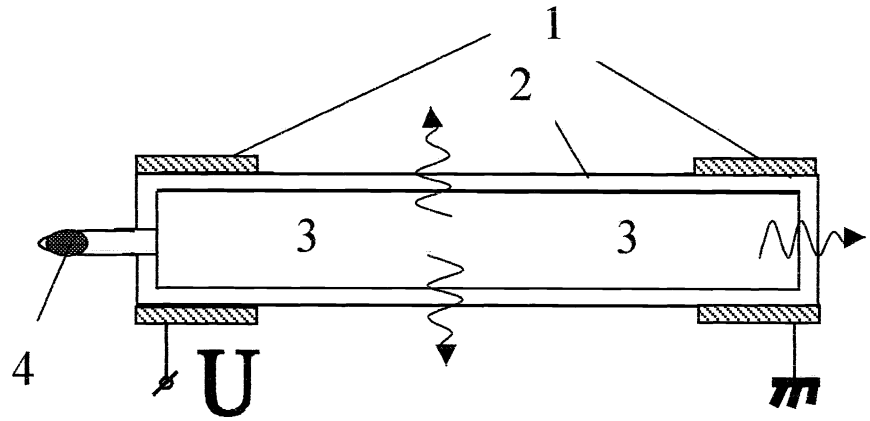


Fig. 2. Design of capacitive discharge excilamps: 1- electrodes, 2- quartz bulb, 3 – gas-vapour mixture, 4 – iodine in solid state.

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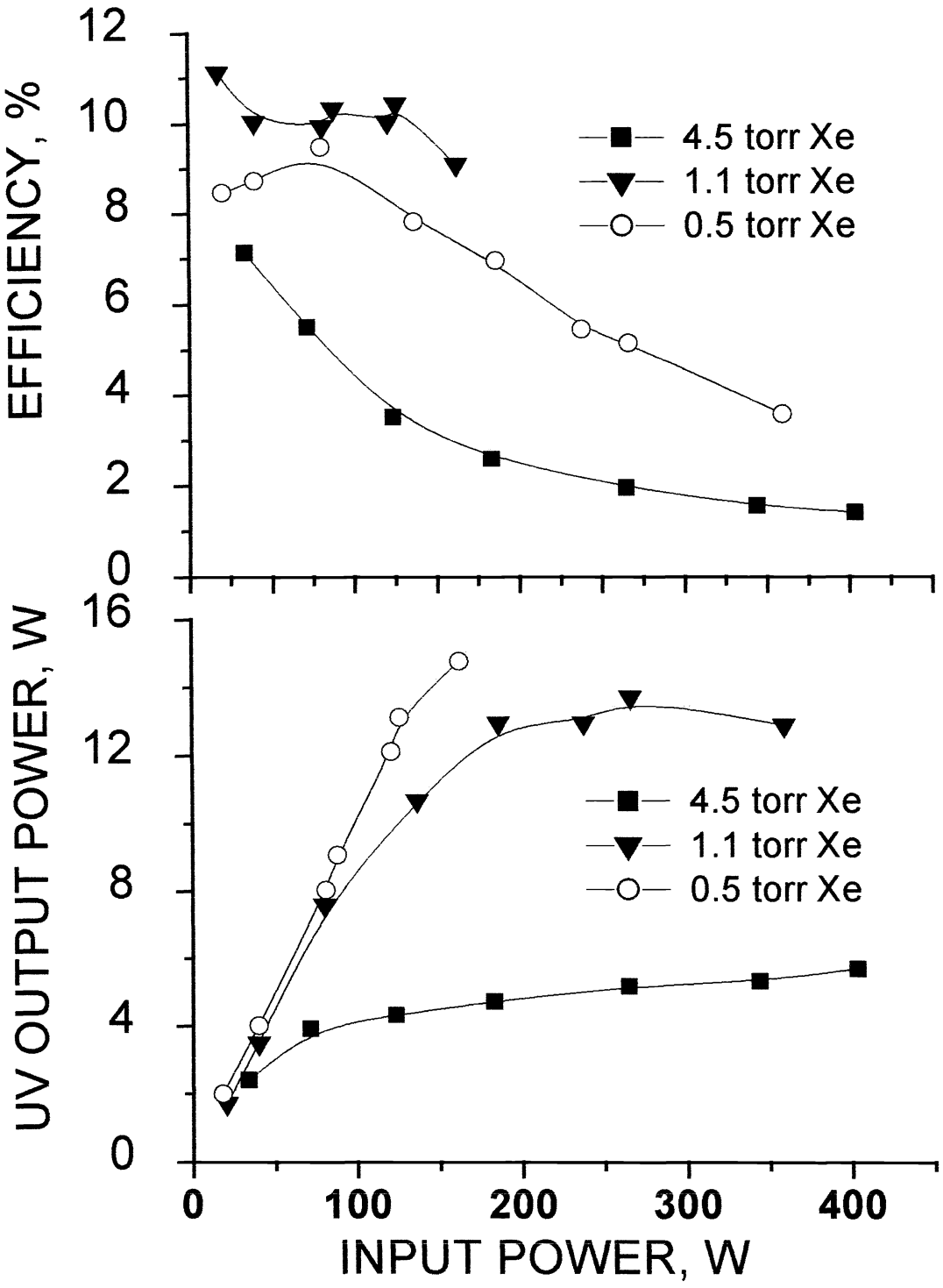


Fig. 3a. Efficiency and UV (λ = 206 nm) average output power as a function of input power at various Xe pressure. Xe - I_2 glow discharge tube.

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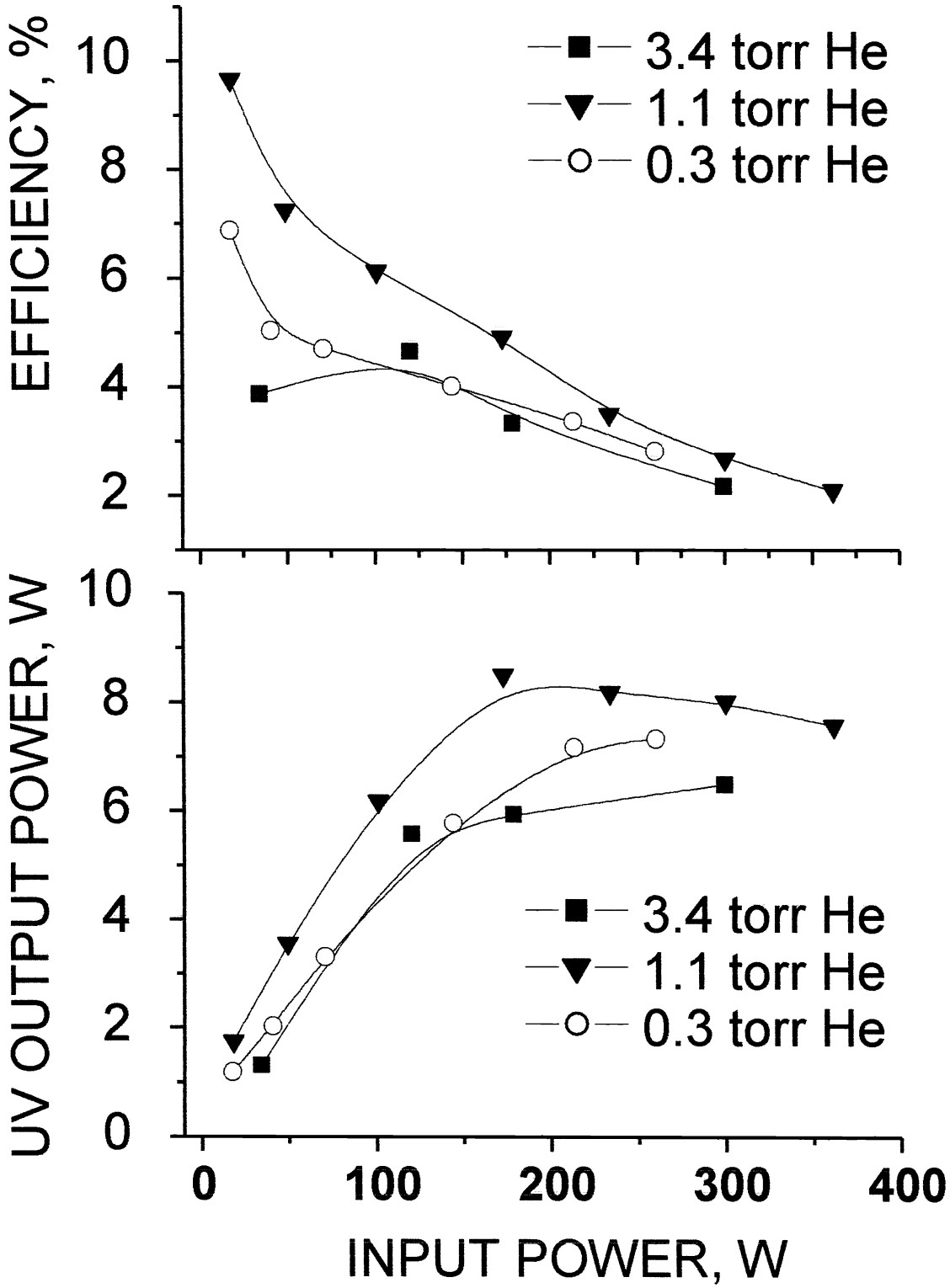


Fig. 3b. Efficiency and UV (λ = 206 nm) average output power as a function of input power at various He pressure. He - I_2 glow discharge tube.

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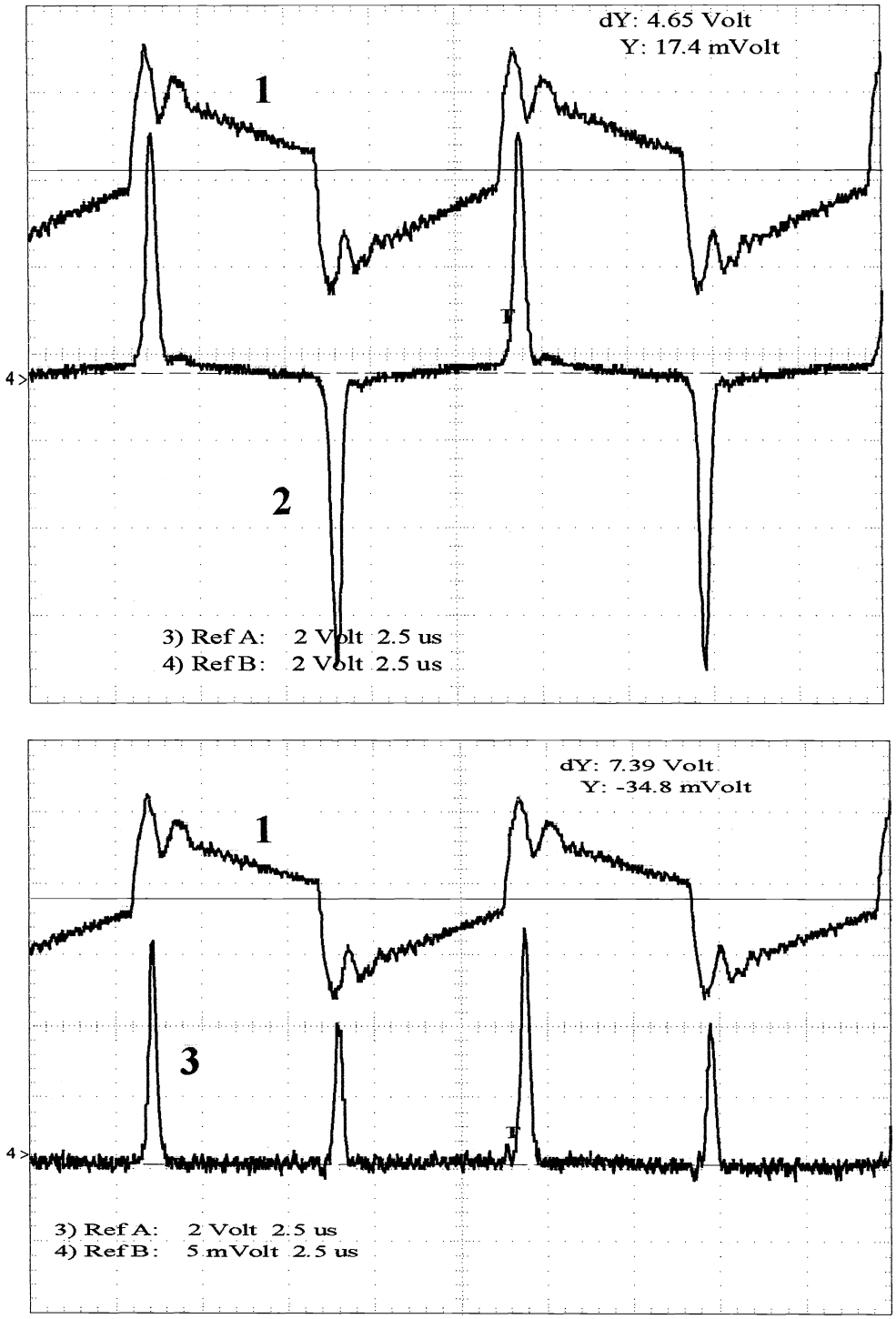


Fig. 4. Oscilloscope traces of Xe-I_2 capacitive discharge excilamp voltage (1), current (2) and UV radiation intensity (3).

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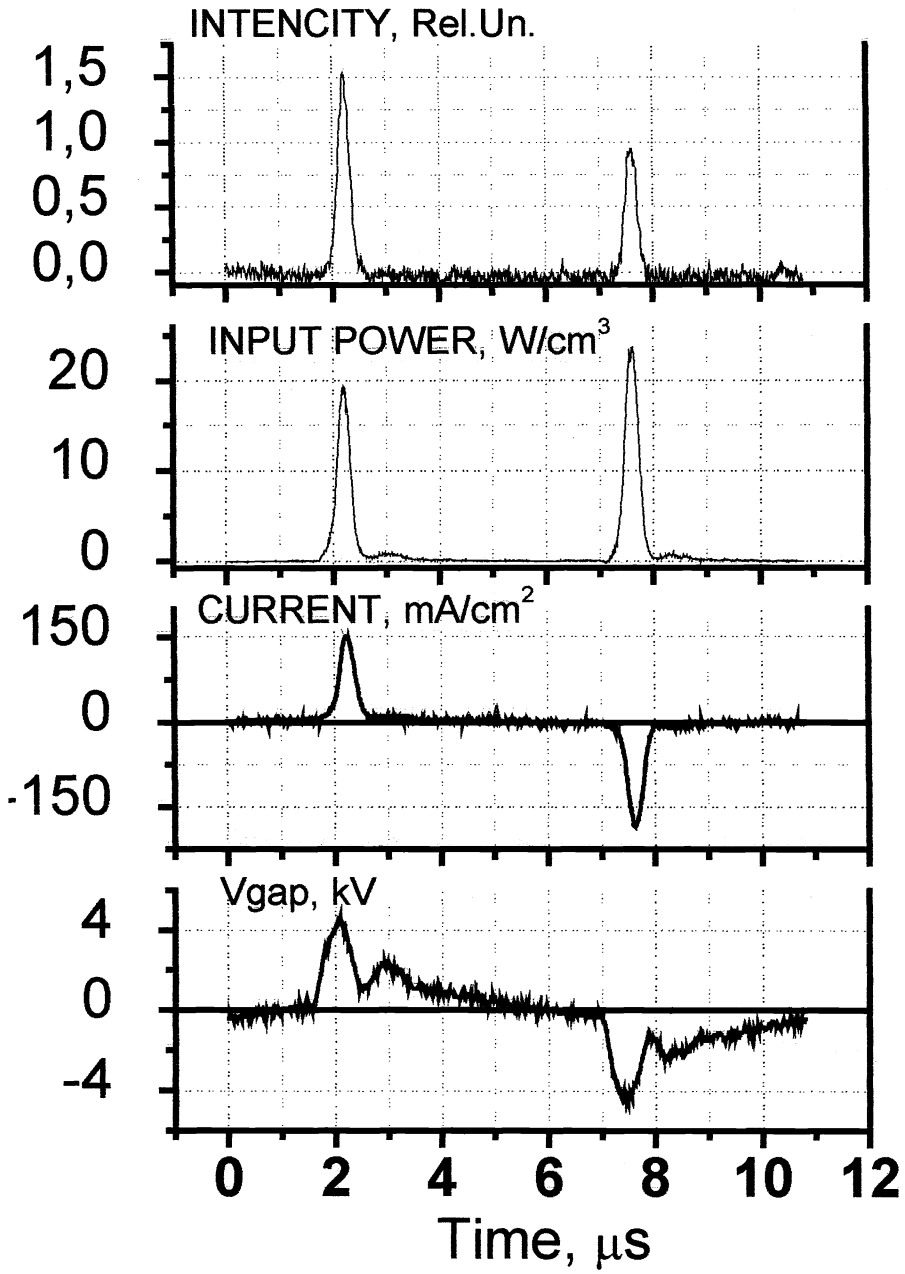


Fig. 5. Oscilloscope traces of Xe-I_2 capacitive discharge excilamp UV radiation intensity, current, calculation curves of input power and voltage on discharge gap.

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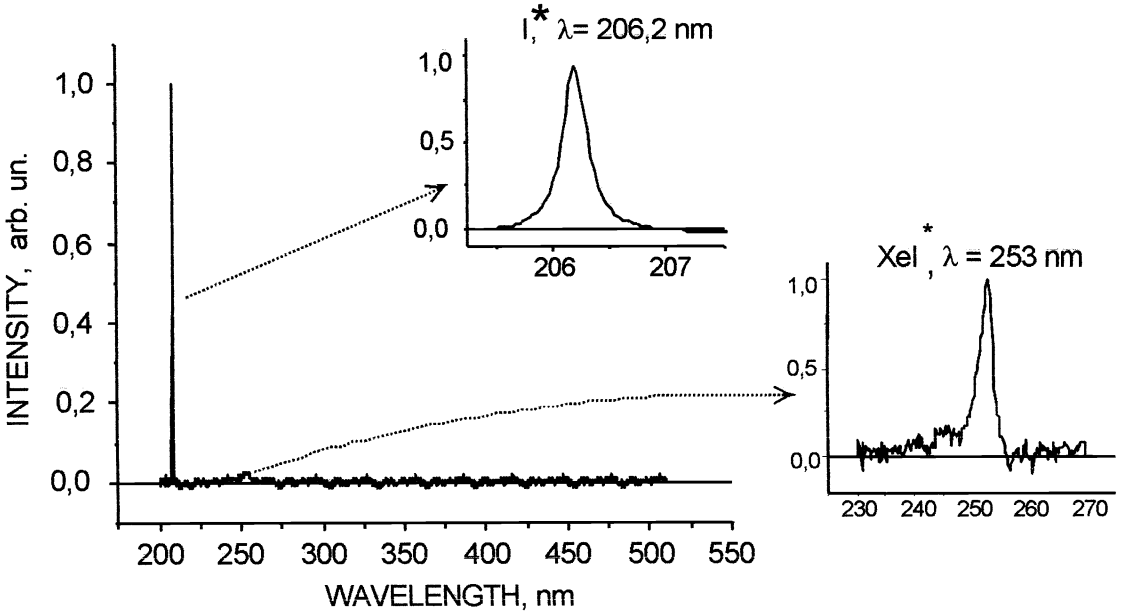


Fig. 6. Xe-I_2 capacitive discharge excilamp spectrum

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