Xenon excilamp excited by transformer and inductive energy storage

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Xe excilamps operating with high efficiency in the VUV spectral region are studied. It is shown that a one-barrier excilamp in comparison with a two-barrier one, all other conditions being the same, operates at lower discharge triggering voltages and has higher optimal pressure. For the first time, excilamp operation is demonstrated at pumping by a high-frequency excitation generator without transformer. In this generator we use inductive energy storage and semiconductor opening switch. A pulse repetition rate of 100 kHz is obtained.

In Refs. 1–3 it was shown that a xenon excilamp ($\lambda \sim 172$ nm) is characterized by a high efficiency when excited by short pulses. Application of a one-barrier excilamp with an internal spiral electrode pumped by unidirectional pulses allowed ~ 40% efficiency of xenon dimer emission to be obtained.[1,2] The high efficiency was also obtained when using an excilamp with two barriers and relatively short excitation pulses.[3] The aim of the experiment described in this paper was to compare discharge triggering voltages and working pressures of xenon excilamps with one and two barriers, as well as to test excitation systems without a transformer but with inductive energy storage. Earlier such an excitation scheme was used to obtain a pulsed discharge with the pulse repetition rate of 12 kHz (Ref. 4).

The excilamps had a traditional design.[1–3,5] The one-barrier excilamp[1,2] was made of a quartz tube with the outer diameter of 30 mm that housed an internal electrode made as a spiral with the step of 6 mm. The spiral was made of a stainless steel wire. The spiral outer diameter was 8 mm, and the wire was 0.9 mm thick. The two-barrier coaxial excilamp[5] consisted of two quartz tubes. The external tube had a diameter of 30 mm and the wall thickness of 1 mm, and the internal one had the outer diameter of ~ 11 mm. The internal tube housed an electrode made as a spiral with the outer diameter of 8 mm. The length of the electrodes on the external tubes of the both excilamps was 40 mm. The electrodes were made of a metal grid with transparency of more than 90%. The xenon pressure in the excilamps can be varied (xenon had the purity of more than 99.998%).

Two generators with a transformer and without it were used to excite the excilamps. The electrical circuit of a high-frequency traditional generator with a transformer and switches-transistors is described in Ref. 6. The generator generated voltage pulses with the repetition rate from 10 to 100 kHz, amplitude up to 5 kV, and duration of 2 μs. The circuit with inductive energy storage was described in detail in Ref. 7. However, transistors were used as switches and the charge voltage was decreased down to 300 V. The second generator generated voltage pulses with the amplitude up to 3.5 kV. The pulse repetition rate was from 10 to 100 kHz, and the full duration of the voltage pulse at halfmaximum was from 0.15 to 0.3 μs (Fig. 1).

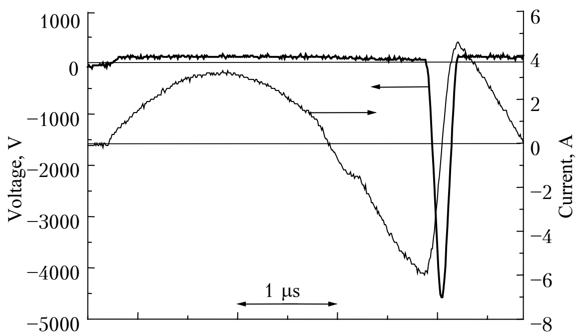

Fig. 1. Oscillograms of current pulses through the semiconductor opening switch and voltage across a load at the pulse repetition rate of 100 kHz and capacitor charging voltage of 300 V.

Voltage and current were measured by ohmic dividers and conducting bridges, whose signals came to a TDS-220 oscilloscope. Radiation emitted by xenon dimers (maximum at the wavelength of 172 nm) was outputted through the walls of the external Suprasil quartz tube, then converted into the UV region with a specialized filter, and finally recorded by an FEK-22 calibrated photodiode, whose signal then came to an F298-3 digital voltmeter.

The main results are shown in Figs. 2 and 3. When using the one-barrier excilamp, breakdown voltage decreases two to three times (all other conditions being the same). Thus, at the 2 μs duration of a voltage pulse, the voltage of 2–2.5 kV was sufficient for initiation of discharge in the one-barrier lamp, while the voltage no lower than 4.5 kV was needed to initiate discharge in the two-barrier excilamp.

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Figure 2 shows the dependence of VUV radiation power on the xenon pressure. The optimal pressure for the one-barrier excilamp was higher even at the lower voltage from the generator.

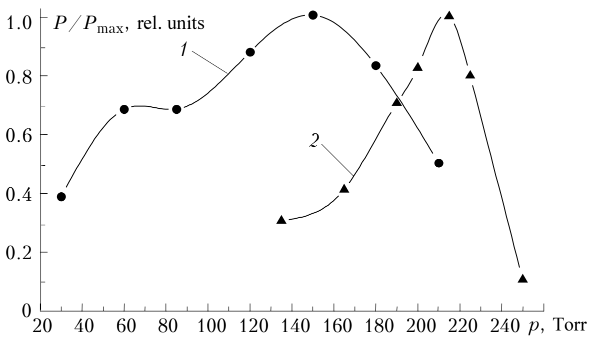

Fig. 2. Mean power of Xe_2^* radiation vs. xenon pressure for the two-barrier (*1*) and one-barrier (*2*) excilamps.

Figure 3 shows the dependence of the mean power of VUV radiation on the mean excitation power at different pulse repetition rates. It can be seen that the maximum emission efficiency is achieved at the pulse repetition rates of 10 kHz (at the pump power up to 4 W) and 30 kHz (at the pump power from 5 to 25 W). This is connected with the conditions of volume discharge generation. The volume character of the discharge is the necessary condition for achieving the high efficiency of a xenon excilamp.

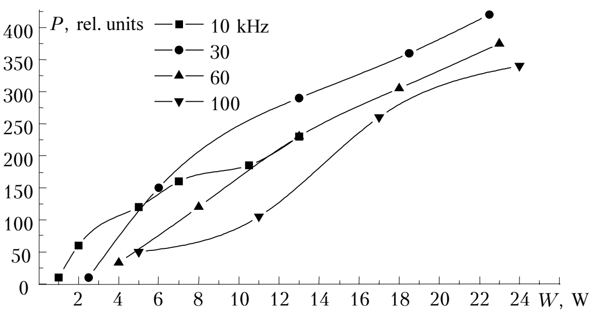

Fig. 3. Mean power of Xe_2^* radiation vs. pump power at different pulse repetition rates for one-barrier excilamp at voltage pulse duration of 2 μs.

At the pulse duration ~ 0.2 μs (generator without transformer but with inductive storage) the power pumped into the gas decreased due to the shorter duration of a pulse at the same repetition rate. However, shortening of the pump pulse usually facilitated generation of a volume discharge. The highest emission efficiency obtained in our experiments was estimated as close to the efficiency of xenon dimer emission in the VUV region obtained in Refs. 1–3 for one-barrier and two-barrier excilamps.

Thus, using xenon lamps emitting with high efficiency in the VUV region, we have shown that the one-barrier excilamp, as compared with the two-barrier excilamp (all other conditions being the same), operates at a lower discharge triggering voltages and has the higher optimal pressure. For the first time, the excilamp operation was demonstrated at pumping by a high-frequency excitation generator without transformer, but with inductive energy storage and semiconductor opening switch at the pulse repetition rate of 100 kHz.

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