Modular Excilamps of Barrier Discharge

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Abstract – In most cases of applications radiation treatment of a surface with a big area at high homogeneity of distribution of UV or VUV power is necessary. For increase of a size radiation surface in modular excilamps two or more parallel radiators are used. In this paper, modular excilamps with operate molecules Kr_2* (146 nm), Ar_2* (126 nm), Xe_2* (172 nm), KrCl* (222 nm), KrBr* (207 nm) and Cl_2* (258 nm) with an output window area up to 550 cm^2 and the specific power up to 120 mW/cm^2 are presented. Means of radiator cooling, photos and design sketches of developments, radiation spectra, and specific power distribution diagrams are presented too.

1. Introduction

First of all, excilamps are simple gas-discharge sources of spontaneous narrow-band ultra-violet (UV) and vacuum ultra-violet (VUV) radiation with high efficiency (in comparison with lasers) and with an opportunity to irradiate a large area of the surface at once (in one step).

Sources of radiation of such type provide the energy of photons from 3 to 10.5 eV, which is sufficient for application of excilamps practically in all known photoprocesses in which UV and/or VUV radiation is necessary [1].

The popularity of excilamp application in various areas of science and engineering is explained by just listed properties.

Modular excilamps are developed with the aim to receive the homogeneous and plane front of radiation with the large area of irradiation. Design of modular excilamps consists in join of two and more radiators with the general power supply and cooling system in one system.

The idea of combination of coaxial radiators is not new and is widely used in the world, and even there are samples of modules which are produced commercially [2]. Constructions of excilamp radiators were represented two coaxial quartz tubes of different diameters soldered at ends. The reflector *6* was placed on a coaxial radiator in one half-plane to receive radiation, and the grid electrode *2* was used to extract radiation (Fig. 1).

The purpose of this article is to present the modular excilamps developed in the Laboratory of Optical Radiation of the Institute of High Current Electronics, Siberian Branch of Russian Academy of Sciences (Tomsk).

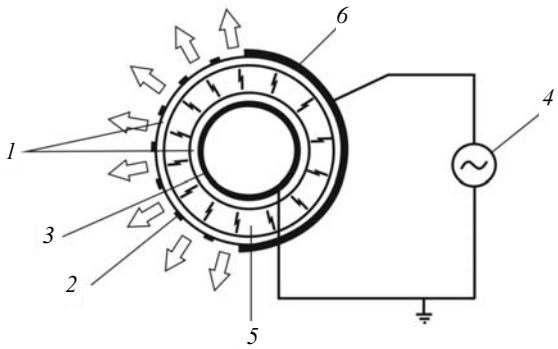

Fig. 1. Excilamp radiator: *1* – quartz tubes; *2* – grid electrode; *3* – reflective electrode; *4* – power supply; *5* – discharge gap; *6* – reflector

2. Modular excilamp on xenon dimers with a high specific radiation power [3]

We succeeded in receiving the record high specific radiation power with wavelength of 172 nm, owing to development of the modular excilamp on xenon dimers (Fig. 2).

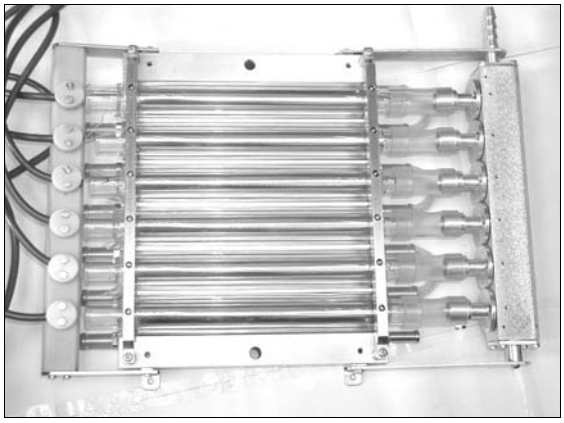

Fig. 2. Xe-excilamp with a high specific radiation power

The module consisted of six radiators of the coaxial design, cooled by water and gas streams. Such module was fed from the six-channel power supply of the power of 2.1 kW. Each radiator was provided by a reflective electrode in such a way that radiation was directed towards an irradiated object. On the surface of radiators the specific radiation power of 120 mW/cm^2 was received, and the total area of the radiating surface of the module was 20×20 = 400 cm^2. Radiation was homogeneous with the specific radiation power of about 80 mW/cm^2 at distance of 10 cm from the surface of radiators.

3. Modular excilamp on krypton and argon dimers for windowless application [4]

To extract radiation of krypton or argon dimers with wavelengths of 126 and 146 nm respectively, the expensive CaF_2, MgF_2, and others quartz windows are frequently used. Therefore, for creation of a large-aperture excilamp with these wavelengths it is practical to use a windowless excilamp design. It means that the irradiated object is placed in a hermetic chamber filled with operating gas where the barrier discharge is formed.

So, the modular excilamp on krypton or argon dimers, developed in our laboratory, included ten quartz tubes, cooled by water, and thirty wire cathodes strained perpendicularly to tubes near to their surface (Fig. 3).

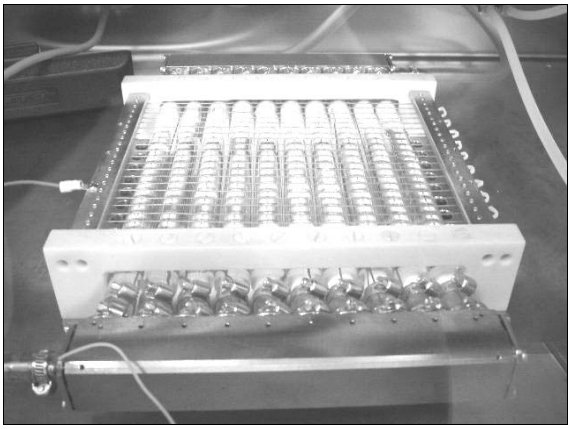

Fig. 3. Windowless modular excimer lamp

The chamber was filled with operating gas and the pulse voltage was applied to cathodes and the barrier discharge consisting of great number of channels in each crossing of a tube and a wire cathode, was ignited. Size of the radiation surface was 22×25 = = 550 cm^2. The specific VUV power was 3 mW/cm^2 for dimers Ar_2* and 5 mW/cm^2 for dimers Kr_2* at distance of 3 cm from the radiation surface.

4. Modular excilamp on exciplex molecules

This excilamp sample has the power supply and two radiators placed in one box, and radiation is directed down and extracted through a quartz plate, fixed in a removable flange (Fig. 4).

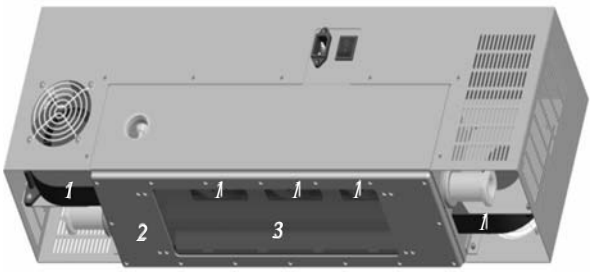

Fig. 4. Modular excilamp on excimer molecules: *1* – cooling fans; *2* – bottom flange; *3* – quartz window

Size of an output window is 320×110 mm. Radiators are cooled by air from two centrifugal blowers, installed on the ends of radiators. We developed the excilamps of such design, operating on KrCl* (λ ~ 222 nm), KrBr* (λ ~ 207 nm), XeCl* (λ ~ 308 nm), XeBr* (λ ~ 283 nm), and Cl_2* (λ ~ 258 nm) molecules. A control board includes the digital timer, which permits to set the time of excilamp work. Radiator fasteners are developed in such a way as to remove and to fix them easily.

Distribution of the specific radiation power is similar for each operating molecule. Fig. 5 shows distribution of the specific radiation power for the KrCl-excilamp.

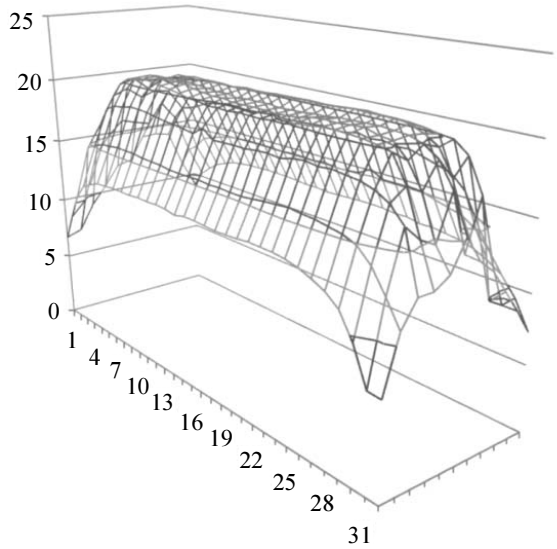

Fig. 5. Distribution of the specific radiation power, mW/cm^2, at distance of 5 mm from the output window of the KrCl-excilamp

5. Excilamp module for flow photoreactors of high pressure [5]

We developed the module of ten one-barrier xenon excilamps with radiator length of 1250 mm each for flow photoreactors of high pressure. Radiator bulbs are made of a quartz tube *1* with outer diameter of 22 mm and inner diameter of 16 mm (Fig. 6). A quartz tube *2* with diameter of 5 mm is coaxial with the tube *1* that is wound round by stainless steel wire *3* with diameter of 0.7 mm and with coil pitch of 10 mm. Thus, a gap between the outer electrode and the inner surface of the tube *1* is 4.8 mm. The outer electrode of the radiator, through which VUV radiation is extracted, is also wound round with nichrome wire *4* with diameter of 0.15 mm. Transparency of the outer electrode is no less than 85%. Length of the radiator surface is 1170 mm. The inlet of the feeding voltage *5* is soldered to one end of the bulb, and the outlet is soldered to another end to inflate the radiator with xenon and to seal it up in the following. Optimum working pressure of xenon in the excilamp bulb is 300 Torr.

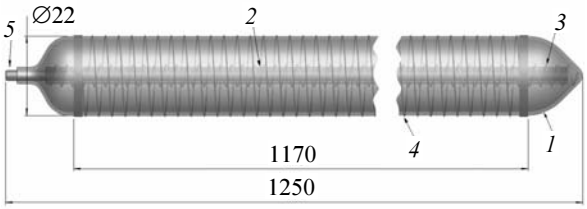

Fig. 6. Radiator of the Xe-excilamp: *1* – outer tube; *2* – inner tube; *3* – spiral cathode; *4* – outer electrode; *5* – electrical inlet of the cathode

To ignite a discharge in the excilamp radiator, the pulse voltage with negative polarity, duration of 2 μs, amplitude of 3.4 kV, and frequency of 40 kHz is applied to the inner spiral cathode *3*, at the same time the outer electrode 4 is grounded. The average specific radiation power of sealed off excilamps is 15 mW/cm^2. The total radiation power of the module is 120 W (each radiator of 12 W). Power supplies for radiators are placed into a hermetic explosion-proof box to work in field conditions. Fig. 7 shows the complex of xenon excilamps with the power supplies. Excilamps were tested successfully under pressure in the photoreactor up to 80 Bar.

The developed modular excilamps were used in various applications in which it was necessary to irradiate a large area of the surface with plane front of radiation. For example, the modular excilamp on xenon dimers with a high specific radiation power and the windowless modular excilamp were used for cleaning of semi-conductor surfaces, the modular excilamp on exciplex molecules for water disinfection, and the module of xenon excilamps was applied to the high pressure photoreactor with a natural gas stream for gas drying.

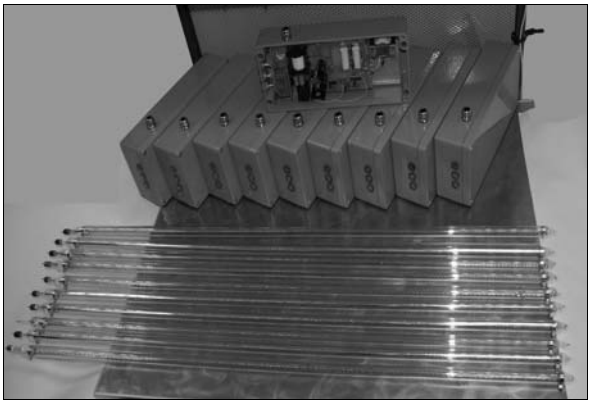

Fig. 7. Xenon excilamp complex with the power supplies

Acknowledgments

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