Optical characteristics of atmospheric pressure dielectric barrier discharge plasma in Ar flow

M. Erofeev (*), V. Skakun, D. Schitz, V. Tarasenko

Laboratory of Optical Radiation, High Current Electronics Institute, Academicheskiy ave2/3., 634055 Tomsk,Russia
(*)mve@loi.hcei.tsc.ru

The energy characteristics of VUV emission of argon dimers excited by a dielectric barrier discharge (DBD) in gas flow at over atmospheric pressures have been studied. Minimal gas velocity allowed to obtain noncontracted discharge with stable power density of radiation due to convectional cooling of discharge gap has been defined. It was shown that at gas flow velocity of 0.5 m^3/h power density of radiation was 100 μW/cm^2. Further increasing of gas flow velocity allows to obtain power density of radiation up to 10 mW/cm^2. The radiation spectra of the lamp consist of the second continuum of Ar_2 molecule with maximum at 126 nm.

Nowadays the most perspective sources of VUV radiation are gas discharge excilamps on hetero- and homo-nucleus of noble gases excited by barrier discharge. The main advantages of DBD excilamps over lamps on resonant transitions of noble gases [1-3] are the following: narrow band emission spectra, higher energy characteristics and life-time, possibility initiate discharge in gas flow, its construction allows transferring radiation through window and also work without it.

Scheme of Ar_2 flow excilamp is shown on fig.1. Formation of the diffuse discharge achieved with using of quartz barrier, as well as, amplification of electric field at the cathode which allowed increase pressure in pulsed excilamps [4, 5]. For VUV output was used window (5) from LiF crystal with diameter of 20 mm. Argon gas flow velocity is controlled by reductor in the range of 0.5 – 10 m^3/h. For excitation of the excilamp, unipolar voltage generator with a pulse repetition frequency variable between 7 and 70 kHz was used. The amplitude of positive voltage pulses was 6 kV of full-width at half-maximum 2 μs.

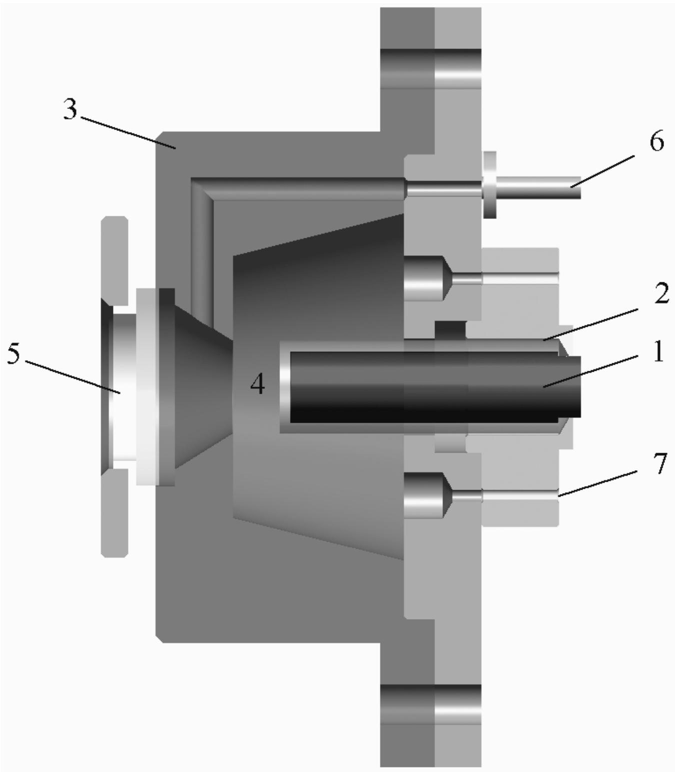

Fig. 1: Scheme of one barrier flow Ar_2-excilamp. 1 – high voltage electrode, 2 – quartz tube, 3 – metal case, 4 – discharge gap, 5 – LiF output window, 6 – gas inlet, 7 – gas outlet

Fig. 2 shows input power dependence of the mean power and efficiency of Ar_2 molecules radiation at gas flow velocity of 0.5 m^3/h. Under low frequencies of voltage pulses (7 – 17 kHz), radiation mean power increased with increasing of input power and discharge form was diffuse. As the input power is further increased, discharge transforms into diffuse channel, resulting in a decrease of radiation power.

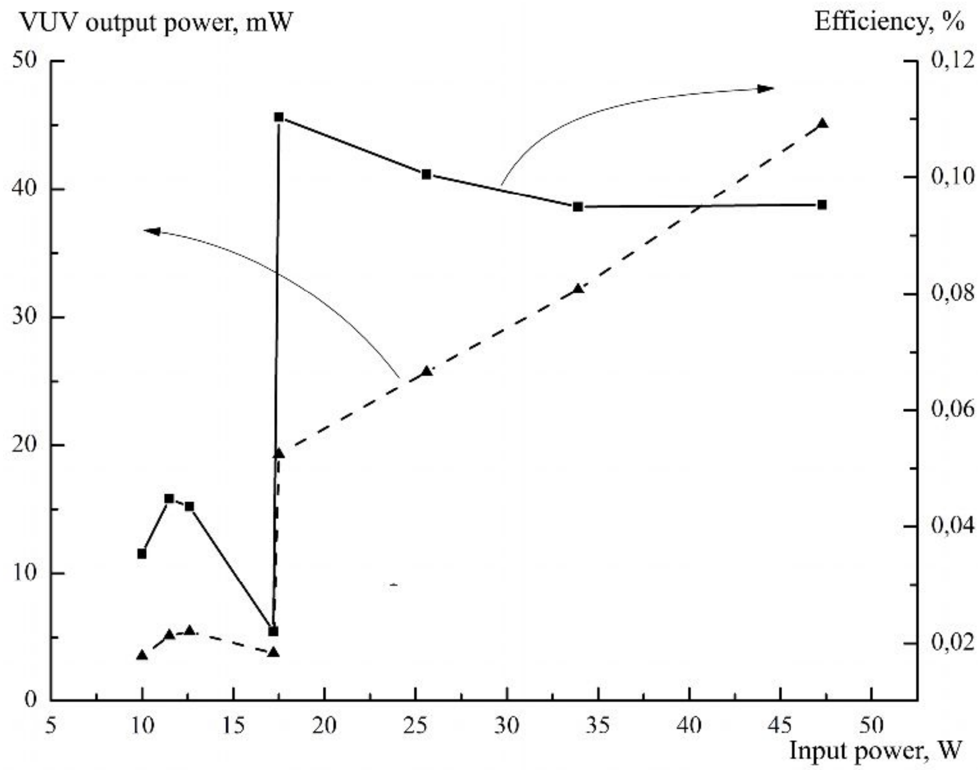

Fig. 2: VUV output power and efficiency of radiation versus input power

At the value of input power of 17.5 W, which corresponds to frequency of 25 kHz, several diffuse microdischarges formed in the discharge gap, resulting in a rapid increasing of power and efficiency of radiation. Further increasing of voltage pulse frequency and, thereafter, input power (from 17.5 to 50 W) led to linear increasing of power density of radiation. However efficiency of radiation of Ar_2^* molecules decreased due to overheating of working gas and exceeding of specific power of pulses of excitation over optimum values. Increasing of gas flow velocity through excilamp provide cooling and stabilization of the discharge because of convective evacuation of gas from discharge region. Value of minimal gas consumption for discharge gap cooling, providing stable output of excilamp radiation, at voltage pulse frequency of 7 kHz, was 0.5 m^3/h. Under this conditions, power density of radiation at the surface of output window was 0.1 mW/cm^2, mean power to the angle of 4π was 7 mW. Increasing of gas flow in ~10 times and voltage frequency up to 70 kHz allowed to reach maximum power density of 10 mW/cm^2 in the case of operation without window. The emission spectrum of Ar_2-excilamp is a wide band with a maximum at 126 nm and corresponds to the second continuum of Ar_2^*.

The obtained VUV power densities of one barrier flow Ar_2-excilamp are comparable with power characteristics of excilamps of UV radiation. Such construction allows initiate diffuse discharges in other noble gas.

References

[1] Budovich V.L., Budovich D.V., Polotnyuc E.B. *Tech. Phys.***76** (2006) 529-531.
[2] Volkova G.A., Shishatzkaia L.P., Yakovlev S.A. *J. Opt. Technol*. (1995) 66.
[3] Shishatzkaia L.P., Yakovlev S.A., Volkova G.A. *J. Opt. Technol*. (1998) 93.
[4] Lomaev M.I., Skakun V.S., Tarasenko V.F. *Tech. Phys. Lett*.**32** (2006) 590-592.
[5] Baksht E. Kh., Lomaev M.I., Rybka D.V. *Tech. Phys. Lett*.**32** (2006) 948-950.