PULSED HIGH POWER SOURCE OF SPONTANEOUS EMISSION IN THE VACUUM UV SPECTRAL REGION

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Results are presented of studies of a pulsed high power source of spontaneous emission (excimer lamp) at wavelengths 126, 146, or 172 nm *using dimers of argon, krypton, and xenon, respectively. Power densities* 1 mW/cm^2 *averaged at* λ = 146 *and* 172 nm *for a beam* 10 cm *in diameter are obtained, while power density of emission* of λ = 172 nm *was about* 0.5 kW/cm^2.

1. INTRODUCTION

Currently high power sources of UV and VUV radiation find expanding applications to various areas of science and technology. Both coherent[1] and spontaneous[2] radiations are used. Sources of spontaneous radiation are distinguished by simplicity and long service life. However, they cannot yield significant densities of either pulsed or averaged radiation power and suffer great radiative losses when distance increases between the source and the target. We constructed a wide-aperture exciplex lamp[3] producing a beam about 10 cm in diameter and radiating high power pulses at λ ~ 308, 250, 350, and 222 nm.[3] Pulsed volumetric discharges are produced in pressurized rare gas-halide mixtures. Radiation power densities up to 2 kW/cm^2 are reached. Such lamps may find use in microelectronics, biology, medicine, and ecology, to destroy harmful substances.

This paper reports on a pulsed discharge VUV lamp with an output aperture 10 cm in diameter and a pulse output power density of 0.5 kW/cm^2, operating by emission of rare gas dimers.

Rare gas dimers excited by either an electron beam or electric discharge are long known[4,5] to fluoresce at high efficiency (~ 50%). Recent calculations are available of argon and xenon dimer yields in self-sustained discharge,[6] which discount discharge constriction limiting duration of the volumetric stage of the discharge at elevated pressures

2. EXPERIMENTAL SETUP AND METHODS

The design of the excimer lamp is similar to the exiplex one, described earlier.[3] The radiating element consists of a 4 liter gas discharge cell and a power generator. The cell contains 2 main electrodes, one of which is a circled profiled disk and another is meshed; spark gaps of the preionization system circle the discharge space and are serially connected to peaking capacitors. The generator follows the double-circuit scheme with the capacitors of the KVT–3 type. The main storage element has a capacity of 4 nF, its discharge circuit inductance reaches about 30 nH. The total capacity of the peaking capacitors is 2.5 nF.

Radiation at λ ~ 146 and 172 nm exits to atmosphere through a ~ 90 mm CaF_2–window behind the meshed electrode of geometric transparency of 70%.

We used helium, neon, argon, krypton, and xenon of high purity for our experiments, impurities remain below 0.01%. Amplitude-temporal and spectral characteristics of radiation were measured in argon (λ ~ 126 nm), krypton (λ ~ 146 nm), and xenon (λ ~ 172 nm), and in mixtures of these gases with helium and neon as buffer gases. Measurements were taken both in the quasi-sealed regime where the lamp was filled with either gas or mixture, and in the regime of continuous pumping of gas through the discharge space. Due to continuous supply of fresh gas mixture the radiant power did not decrease in such *t* continuous mode, and operating discharge frequency reached 30 s^{-1}.

Pulse power and duration for the excimer lamp were measured by a sodium salicylate spectral converter and a FEU–140 photomultiplier, both were pre-calibrated by the ArF–laser. To record VUV emission spectra a 600 div/mm VMR–2 grating vacuum monochromator was used, calibrated by emission lines from a hydrogen lamp.[7]

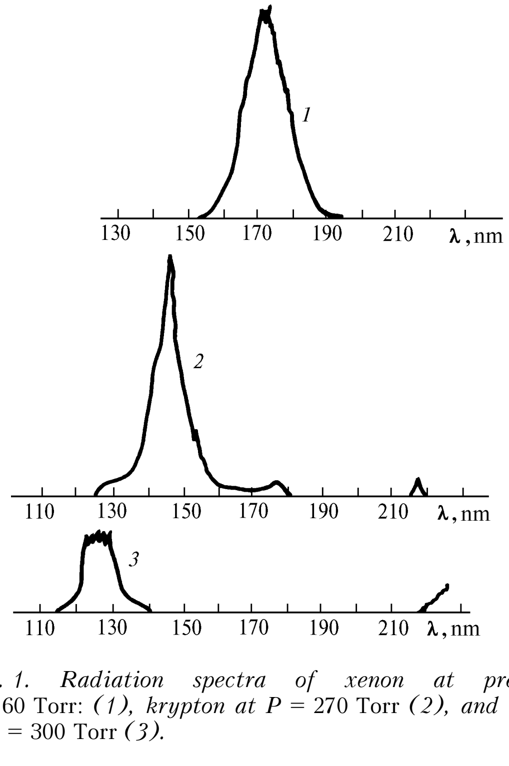

FIG. 1. Radiation spectra of xenon at pressure P = 60 Torr: *(1), krypton at P* = 270 Torr *(2), and argon at P* = 300 Torr *(3).*

3. RESULTS AND DISCUSSION

Figure 1 shows VUV emission spectra of an excimer lamp radiating in rare gas dimer transitions from low vibrational levels of the $^{1,3}\Sigma_u^+$ state to the ground $^1\Sigma_g^+$ state.[4-7] Radiation intensities in the maxima of the Xe_2, Kr_2, and Ar_2 emission continuums and pulse widths at FWHM are

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presented in Figs. 2*a*, 3*a*, and 4*a*. Pressures optimal for maximum dimer emission by Xe, Kr, and Ar are 150, 240, and 300 Torr, respectively. Further increase in pressure works to reduce the intensity because of the contraction of volumetric discharge. Spark discharges yield very low dimer fluorescence due to the high electron density and gas temperature. Using buffer gases (helium and neon) improves the stability of volumetric discharge and increases the operational repetition rate. Moreover, as compared to single working gas, the radiant power in binary mixtures is not reduced, and in some cases it even increases. Nevertheless, adding buffer gas significantly increases the radiant power from xenon, krypton, and argon dimers at operating gas pressures which are only 2–3 times below their optima.

In other words, when adding 600 Torr of neon to 150 Torr of xenon the radiant power increases 20% only, while adding 600 Torr of helium it is halved. This reduction of radiant power results from discharge contraction. Our experiments yielded a ratio of 12:6:1 for the maximum pulse powers of the dimers, P_{Xe}: P_{Kr}: P_{Ar}. Mean radiant power density exciting the lamp window at $\lambda \sim 172$ and 146 nm is 1 mW/cm^2 for the Xe(Kr) : He = 1:15 mixture, at a total pressure of ~ 1 atm. Pulse power density at $\lambda \sim 172$ nm reaches 0.5 kW/cm^2. Optimally, pulse widths at $\lambda \sim 126$ (Ar_2^*), 146 (Kr_2^*), and 172 nm (Xe_2^*) were close to each other, equalling 500, 500, and 600 ns, respectively. Beam diameter immediately behind the window was about 10 cm, and its inhomogeneity across the spot of the same diameter at the distance of 8 cm from the window, remained within 10%.

4. CONCLUSION

The present paper reports on an excimer discharge lamp with a 10 cm output window, operating in the VUV spectral region. Mean power density at $\lambda \sim 172$ and 146 nm is 1 mW/cm^2, peak power density at $\lambda \sim 172$ nm is ~ 0.5 kW/cm^2. Pulse repetition rate of the lamp reaches 30 s^{-1}. Radiation from such lamps may be used in microelectronics for dry photoinitiated etching, precipitating, and cleaning; in ecology, to destruct toxic organic substances; in biology and medicine, for water disinfection, in particular.

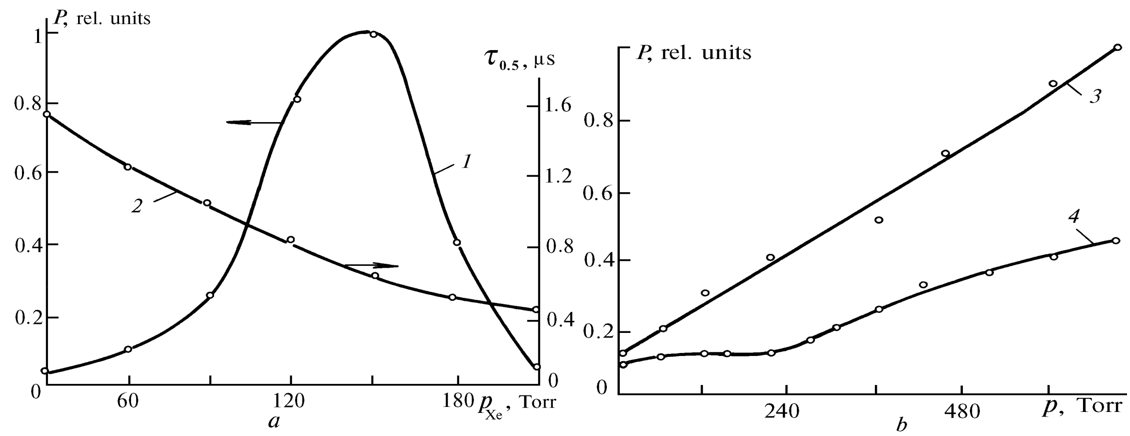

FIG. 2. Radiant power at $\lambda \sim 172$ nm *(1) and pulse width at FWHM (2) vs pressure of xenon (a). Radiant power at* $\lambda \sim 172$ nm *vs pressure of heliwn (3) and neon (4) buffer gases, at* 60 Torr *of xenon (b).*

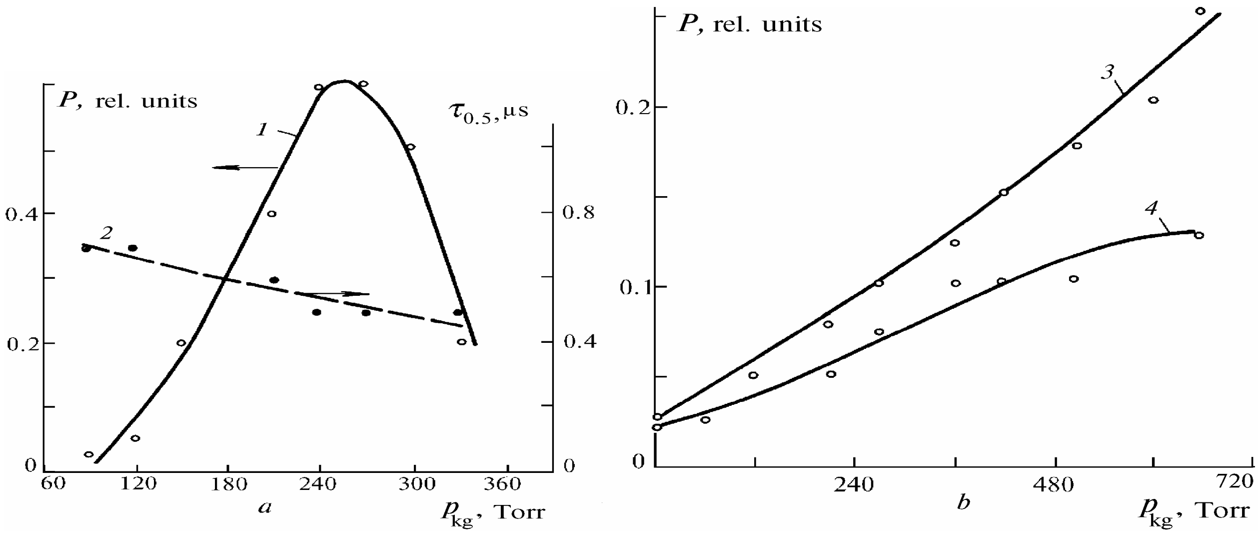

FIG. 3. Radiant power (1) and pulse width (2) at $\lambda \sim 146$ nm *vs pressure of krypton (a). Radiant power at* $\lambda \sim 146$ nm *vs pressure of helium (3) and neon (4) buffer gases, at* 90 Torr *of krypton (b).*

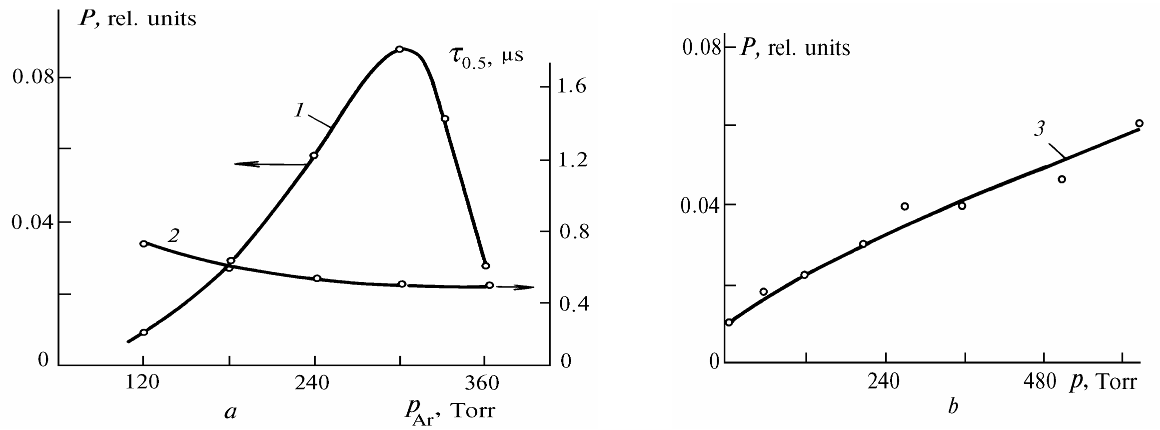

FIG. 4. Radiant power (1) and pulse width atFWHM (2) at λ ~ 126 nm *vs pressure of argon (a). Radiant power at* λ ~ 126 nm *vs pressure of helium (3), at* 120 Torr *of argon (b).*

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