NEW MECHANISM OF COHERENT-RADIATION GENERATION IN THE VISIBLE REGION OF THE SPECTRUM IN IONIZED OXYGEN AND NITROGEN

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It is known that stabilized free radicals are produced, and accumulate under appropriate conditions, in a discharge in an atmosphere of nitrogen and oxygen [1]. The use of the energy stored in these radicals for laser pumping is of great interest. In this connection, we have attempted to use the stored energy in free radicals stabilized on the walls of a discharge tube to obtain generations on nitrogen and oxygen transitions. Generation on the transitions of atomic and ionized nitrogen and oxygen was investigated in [2 - 6], where generation was obtained on 16 lines of oxygen and 11 lines of nitrogen in the range from 2983 to 6721 Å, and it was shown that it is impossible to produce inverted population in pure nitrogen and oxygen by collisions with electrons alone. Therefore to obtain generation, the oxygen and nitrogen were introduced as an impurity in argon or neon. The N_2 and O_2 molecules colliding with Ar or Ne atoms in the metastable state, dissociated with formation of N and O, likewise in metastable states. Because of the large cross section for the interaction of these states with the electrons, the generating levels become inverted. The experiments were performed with the setup illustrated in Fig. 1. The discharge was produced in a water-cooled quartz tube 1 m long. The pressure in the system was smoothly regulated with leak valves, the gas flowing through at pressures 6×10^{-1} to 1.5×10^{-2} Torr. The evacuation was with a forevacuum pump with a nitrogen trap. A capacitor bank, the rating of which was varied during the experiment from 75 to 600 μF, and the voltage from 3 to 7 kV, was discharged through an adjustable gap between internal electrodes in the tube. The discharge current registered by a Rogowski loop reached 3 kA at a pulse duration up to 3 msec. The resonator was made up of spherical mirrors with dielectric coating for the corresponding wavelength region. In the investigation of the influence of the discharge capacitance (75, 150, 300, 600 μF) and tube diameter (5, 8, 12 mm) on the generation power it was found that the largest value of the power occurs at a tube diameter 8 mm and C = 300 μF. The subsequent results will therefore refer to these values. Generation was obtained on eight lines (6721 Å, OII; 6666.94 Å, OII; 5679.562 Å, II; 5666.62 Å, II; 5592.37 Å, OIII; 5146.06 Å, OI; 5016.387 Å, II; 4772.91 Å, OI).

To obtain generation, a preparatory pulsed discharge (4.5 - 5.5 kV) was first produced, during the course of which there was no generation. Generation was then observed during several working pulses (U = 3 - 4 kV), and its intensity decreased exponentially with increasing number of the working pulse (Fig. 2). The interval between pulses was 10 sec. The observed number of generation pulses after the preparatory discharge depended on the voltage of the latter and on the voltage of the working discharge, and also on the interval between pulses. This effect was observed both for oxygen and nitrogen. The N and O

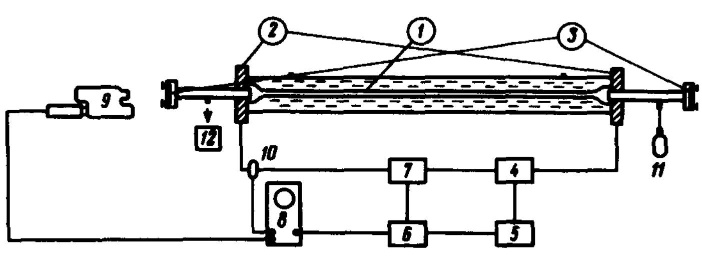

Fig. 1. Block diagram of setup: 1 - discharge tube, 2 - electrodes, 3 - dielectric mirrors, 4 - capacitor bank, 5 - rectifier, 6 - triggering device, 7 - controlled discharge gap, 8 - oscilloscope, 9 - monochromator with photomultiplier, 10 - Rogowski loop; 11 - flask with leak valve, 12 - forevacuum pump.

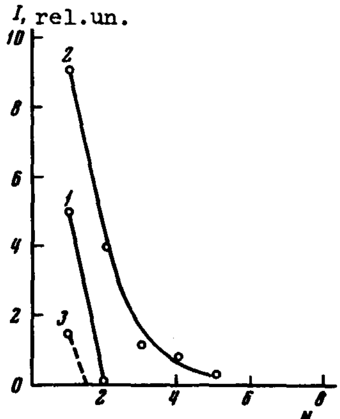

Fig. 2

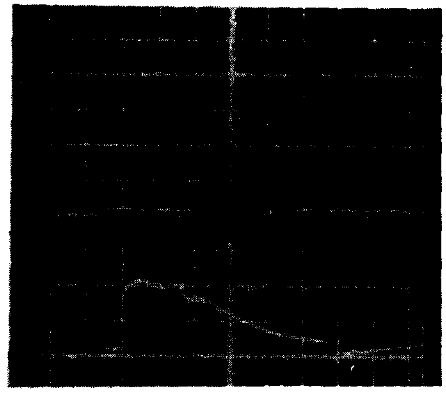

Fig. 3

Fig. 2. Dependence of the generation intensity on the number of the "working" pulse (U_{prelim} = 5 kV, p_{N_2} = 1.5 × 10^{-1} Torr. 1 - U_{disch} = 3.6 kV, 2 - U_{disch} = 3.8 kV, 3 - U_{disch} = 4.0 kV).

Fig. 3. Oscillogram characterizing the time relations between the discharge current (lower trace) and the generation pulse (upper trace). Sweep duration 300 μsec/cm.

admixtures did not exceed 0.01 - 0.1%. The generation lasted from several dozen to several hundred microseconds, depending on the voltage and pressure in the tube. The maximum generation power reached 2 W at 3.6 kV and 8 × 10^{-2} Torr, corresponding to the optimal Ep^{-1} V-$cm^{-1}Torr^{-1}$. A typical oscillogram characterizing the time relations between the discharge current and the generation pulse is shown in Fig. 3.

The population of the generating levels in nitrogen and oxygen is determined by the number of metastable states of these atoms [4]. In our case the formation of metastable states of N and O was not a result of the collisions with the inert-gas atoms [2 - 5], but the result of dissociative recombination occurring during the time of the preparatory and working pulses in accordance with the reactions [7, 8]:

$$N_2^+ + e \rightarrow N(^2P) + N(^2D) \quad (1)$$

$$O_2^+ + e \rightarrow O' + O''(^2P;\ ^1D;\ ^1S)\ . \quad (2)$$

These reactions are characterized by large yield coefficients ($\alpha \approx (1 - 2) \times 10^{-7}$ cm^3/sec). We observed that nebular lines with λ = 3467 Å and λ = 5577 Å always accompanied these reactions. Owing to the large lifetimes in the excited states, the atoms N and O reach the walls of the tube and become stabilized on them as a component part of the free radicals [1, 6, 7]. During the preparatory discharge, no generation was observed. Nor was it observed even when several such pulses were applied in succession. The absence of generation can be attributed to the fact that the threshold conditions for its occurrence were not satisfied in these cases. If there was no preparatory discharge prior to the working discharge, then generation was likewise not observed, even if the working discharge was repeated several times. On the other hand, if a working discharge followed a preparatory discharge then, besides the creation of metastable states of the atoms in the discharge, stabilized radicals were detached from the tube wall and increased the density of the metastable states of N and O. This was followed by pumping of the laser levels, owing to the large cross section for the interaction of these states with the plasma electrons. Contributing to the inverted population on the generating transitions was the large rate of decay of the lower laser level, connected with a transition ground state lying in the region of the vacuum ultraviolet.

Thus, generation is obtained during the time of the working pulses by using the energy stored in the free radicals stabilized on the tube walls, including the metastable states of nitrogen and oxygen.

In conclusion, the authors are grateful to Ya.B. Fainberg, L.I. Bolotin, and V.P. Tuchinskii for interest in the work and for useful discussions.

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ERRATUM

In the article by N. P. Gadetskii et al., Vol. 14, No. 3, p. 101, the sentence beginning on the last line of the text reads: "The N and O admixtures..." It should read "The Ne and Ar admixtures..."