Letters to the Editor

OPTIMUM OPERATING MODE OF AN OPTICAL QUANTUM GENERATOR USING A NEON-HELIUM MIXTURE

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In describing an optical quantum generator using a neon-helium mixture, it is customary to cite its individual operating modes at which some radiation power is obtained[1,2]. It would be interesting to trace over broad limits the change in the radiation power during the variation in the discharge conditions.

We report here the results of an investigation of the dependence of the generator output power on supplied high-frequency power, total and partial gas pressure in the tube, and length of the discharge gap.

The investigations were carried out on generators of two kinds, which used a system with plane mirrors and a system with a plane and spherical mirror as the resonator. The radius of curvature of the spherical mirror in the latter system was R = 1998.8 mm; the flat mirror is mounted at a distance equal to half the radius of curvature of the spherical mirror.

The discharge was excited by a high-frequency generator at 39.5 Mc. Light filters with a transmission half-width of 50 Å were used to separate the emission of the 11530 Å line. The measurements were made with the aid of an FÉU-22 photomultiplier. The recording unit was calibrated in absolute units of power by means of a ribbon tube with a known brightness temperature.

The results of the measurements for the generator with the spherical mirror are shown in Figs. 1, 2, and 4. The variation of the generated light-beam power P_{out} as a function of the high-frequency supply power of the tube is presented in Fig. 1 for different pressures (from 0.7 to 4.1 mm Hg) of the neon and helium gas mixtures. It is seen from Fig. 1 that generation starts at a gas pressure on the order of 1—2 mm Hg, when 10—20 W is delivered to the tube; a linear growth in the radiation intensity is observed as the power is raised to 40—50 W, after which a further increase

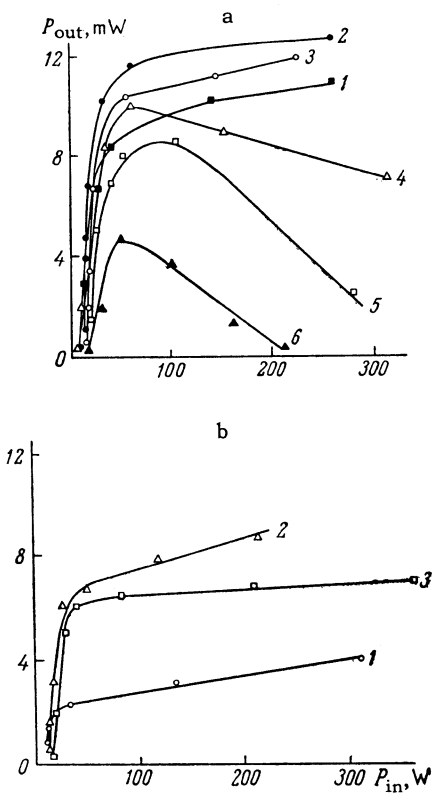

FIG. 1. Dependence of the radiation power of an optical generator using a neon-helium mixture on the high-frequency discharge power for a relative pressure of neon and helium in the mixture of a – 1:9; b – 1:19. Curve 1 – for a mixture pressure of p = 0.7; 2 – for p = 1.4; 3 – for p = 2.1; 4 – for p = 2.7; 5 – for p = 3.5; 6 – for p = 4.1 mm Hg. (Spacing between electrodes was 33 cm.)

in power leads to an insignificant increase in the radiation intensity, which becomes saturated. For higher gas-mixture pressures (to 4 mm Hg) a radiation maximum is observed at 50—80 W of high-frequency supply power and the radiation intensity drops until generation ceases when the supply power is increased further. Maximum generation power is obtained at 1.4 mm Hg of total helium and neon pressure.

Curves showing the dependence of the generation power on the supply power for a 1.4 mm Hg mixture pressure are recorded in Fig. 2 for different partial gas pressures. It is seen from Figs. 1 and 2 that the following conditions are optimum for generation: total pressure 1.4 mm Hg; pressure ratios $p_{Ne}/p_{He} = 1/9$, and 50 W delivered discharge power. Under such conditions the radiation power of the optical quantum generator with the spherical mirror was 12—15 mW.

The dependence of the output power of the generator with the flat mirrors on the supply power is presented in Fig. 3. Generation starts with a

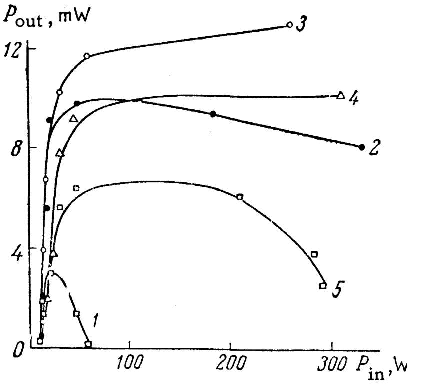

FIG. 2. Dependence of the radiation power of an optical generator using a neon-helium mixture on the high-frequency discharge power for different partial pressures in a mixture with the total pressure p = 1.4 mm Hg; Curve 1 – for p_{Ne}/p_{He} equal to 1/2; 2 – 1/4; 3 – 1/9; 4 – 1/19; 5 – 1/39.

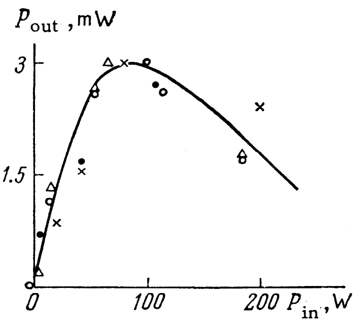

FIG. 3. Dependence of radiation power on high-frequency discharge power for an optical generator with flat mirrors; p = 1.4 mm Hg; p_{Ne}/p_{He} = 1/9. x, Δ – high-frequency power varied from 0 to 200 W; ●, o – from 200 to 0 W.

5–10 W supply power in the tube; its maximum intensity of 3 mW is achieved for a supply power of about 80 W.

The investigation of the dependence of the generation power on the length of the discharge gap (Fig. 4) shows that the generation intensity increases in proportion to the length of the discharge gap for the same high-frequency power delivered per unit length of the tube. The minimum length required for the onset of generation is 100 mm for the spherical resonator and 150–200 mm for the resonator with the flat mirrors.

The behavior of the curves can be explained qualitatively thus. An increase in the supply power leads to a growth in electron density in the plasma, to a diminution in the electron temperature and, therefore, to an increase in the role of collisions of the second kind with the electrons, which lead to a near-Boltzmann distribution of the atoms over the excited levels, i.e., to cessation of generation.

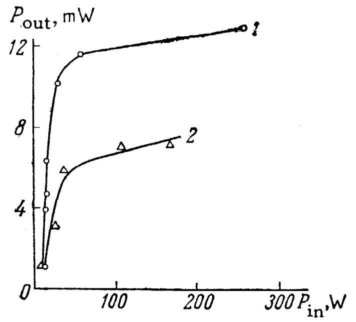

FIG. 4. Radiation power of an optical generator for different discharge-gap lengths (p = 1.4 mm Hg; p_{Ne}/p_{He} = 1/9): Curve 1 – l = 33 cm; Curve 2 – l = 15 cm.

The higher the gas pressure (see curve 6 of Fig. 1a), the smaller the role of the processes, that reduce the plasma to equilibrium at a lower supply power (starting with 50 W at a gas mixture pressure of 4 mm Hg). On the other hand, since collisions of the second kind with excited helium atoms (2^3S) play a fundamental part in the creation of nonequilibrium populations of the $2s_4$ level of the neon atoms, a decrease in the He content of the mixture (see curve 1, Fig. 2) leads to the equalization of the $2s_4$ and $2p_7$ populations at lower discharge current densities.

Hence, the obtained experimental results show that it is impossible to raise the power of the generated radiation above a definite value by increasing the high-frequency power supplied to the discharge tube, because the plasma approaches equilibrium.

In conclusion, the authors are grateful to M. P. Vanyukov for interest in the research.

[1] Javan, Bennett, and Herriott, Phys. Rev. Lett. **6**, 106 (1961).
[2] D. R. Herriott, J. Opt. Soc. Amer. **52**, 31 (1962).

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