INVESTIGATION OF A NEON-HYDROGEN LASER AT LARGE DISCHARGE CURRENTS

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Results are given of an investigation of the emission spectrum of a Ne-H_2 laser at high current densities from the hollow cathode. Seventeen lines of the 2s-2p transition series of neon in the 0.94—1.4 μ range were produced at cathode current densities of 260 mA/cm^2.

In a hollow-cathode discharge in a mixture of neon and hydrogen, the de-excitation of metastable neon atoms by collision with hydrogen molecules makes it possible to decrease the population of the 2p neon level and hence to achieve population inversion between the 2s and 2p levels [1]. In [1] a study was made of laser action in a hollow cathode discharge in Ne-H_2, but the discharge currents used were not enough to saturate the laser power. It is of interest to investigate the operation of the Ne-H_2 hollow cathode laser at large current densities.

The investigation of the behavior of the laser for large discharge current densities was made with a laser having a discharge tube made of stainless steel 7.5 cm long and 1 cm i.d. Multi-layer mirrors with a 100 cm radius of curvature were used, placed 60 cm apart; the mirrors had their maximum reflectivity in the region of 1.1 μ.

In order to avoid intense heating and pulverization of the hollow cathode at large current densities, the measurements were made under pulsed conditions. The constant discharge time was between 5 and 10 μsec, which was long enough to allow us to consider all discharge processes to be in the steady state.

The radiation was detected with a PGS-2 spectrograph using a Zeiss diffraction grating; either a FEU-22 photomultiplier or an electro-optic image converter was placed at the spectrograph output.

In Fig. 1 we give the dependence of the laser output power at 11143 Å on the discharge current for various ratios of the pressures of neon and hydrogen. The oscilloscope sweep was generated by a voltage proportional to the discharge current. It is clear from Figs. 1b and 1c that saturation of the laser power for pressures of neon and hydrogen close to the optimum occurs for currents between 4 and 6 amperes; the current density is between 170 and 260 mA/cm^2.

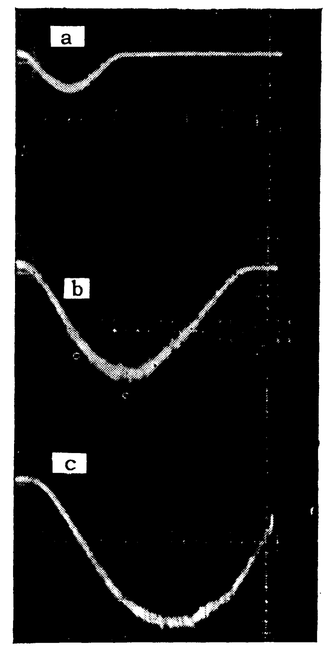

FIG. 1. Dependence of the output power at 11143 Å on discharge current for various ratios of the pressures of neon and hydrogen: a – p_{Ne} = 0.6, p_{H_2} = 0.4; b – p_{Ne} = 0.6, p_{H_2} = 0.8; c – p_{Ne} = 0.6, p_{H_2} = 1.2 all in mm Hg (a large scale division is 2 A).

When the active length of the discharge was increased to 15 cm, laser action was observed for the same discharge conditions on five lines in the 2s-2p group of transitions: 11143, 11177, 11523, 11525 and 11789 Å. In order to obtain laser action on the largest possible number of lines a laser was constructed with an active discharge length 300 cm long. The resonator of the laser was formed with external spherical mirrors with radii of curvature 400 cm, placed a distance about 400 cm apart. The construction of the tube and the method for exciting it are shown schematically in Fig. 2. The maximum discharge current in the pulse was 250 A, Neon lines at which laser action was observed in the neon-hydrogen mixture

	$2s_2$	$2s_4$	$2s_5$		$2s_2$	$2s_4$	$2s_5$
$2p_1$				$2p_6$		11789,1	12066
$2p_2$	11767		13912 *	$2p_7$		11525	
$2p_3$		12689 *		$2p_8$		11143	11390
$2p_4$	11523	12594 *	12912 *	$2p_9$			11177
$2p_5$	11409	12459 *	12767 *	$2p_{10}$		9486 *	9665 *

corresponding to a current density of 260 mA/cm^2. For pressures of neon and hydrogen close to the optimum (p_{Ne} = 0.8 mm Hg, p_{H_2} = 0.8 mm Hg) laser action was obtained on the lines shown in the table. Laser action evidently occurs first in the lines denoted with asterisks.

With silvered mirrors (one of the mirrors was opaque, the other had a transmission of about 1%) simultaneous laser action was observed on the lines shown in the table with the exception of the lines at 9486, 9665, 11409, and 12767 Å. The most powerful laser action under these conditions occurred in the 11143 and 11177 Å lines.

The number of simultaneously oscillating lines and their relative intensities are effected by competing transitions involving common levels of the 2s and 2p groupings. In order to isolate laser action in single transitions and suppress laser action on the competing transitions we used two methods: the first involved use of mirrors having the maximum possible reflectivity at the wavelength desired and small reflectivity at the wavelengths of the competing lines; the second and more complicated method involved the use of a prism in the resonator; this allowed us to separate out individual wavelengths[2]. In order to obtain laser action on the lines 9486 and 9665 Å it was necessary only to weaken laser action on the 11143 and 11177 Å lines by replacing one of the silvered mirrors by an interference mirror having a reflectivity of 97% at 0.95 μ and 65% at 1.1 μ. Under these conditions laser action was also observed at lines 11143, 11523, 11525, 11789, and 12066 Å. Laser action on the lines at 11409 and 12767 Å was obtained only when the prism was used.

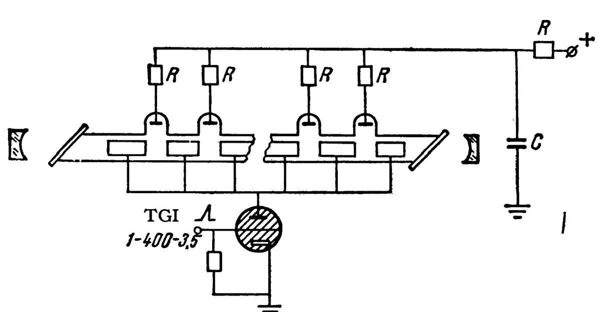

FIG. 2. Schematic diagram of the discharge tube and the exciter. The number of hollow cylinders was 20. Each was 15 cm long, and 1 cm in diameter. The cathode material was stainless steel.

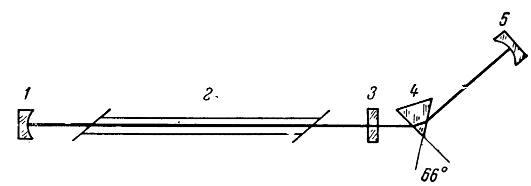

FIG. 3. Diagram of resonator construction for study of the effects of competing transitions.

The line at 11789 Å was ascribed to the $2s_4$-$2p_6$ transition after additional experiments were carried out on the suppression of laser action at 11143 Å by the line at 11789 Å. The diagram of the apparatus is shown in Fig. 3. The resonator, formed by the mirrors 1 and 5, and including a discharge tube 2, and uncoated glass plate 3, and a prism 4, was made to operate at 11789 Å with the help of the prism. For other wavelengths the Q of the resonator formed by mirror 1, the discharge tube 2, and the glass plate 3 was very low due to the small coefficient of reflection of the glass plate. When the mirror 5 was covered, laser action occurred at 11143 Å, owing to the large gain (about 4 dB/m) in this cavity. When laser action was allowed at 11789 Å, laser action at 11143 Å ceased or was significantly decreased, depending on the discharge current. This indicates that the 11143 and 11789 Å lines share a common upper $2s_4$ level.

In conclusion the authors express their thanks to Yu. V. Troitskiĭ for interest in this work.

[1] V. P. Chebotaev, Radiotekhnika i élektronika 10, 2 (1965).

[2] A. L. Bloom, Appl. Phys. Lett. 2, 101 (1963).

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