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Experimental Studies of Uniformity of Positive Column of He-Cd$^+$ Laser Discharge

by

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Summary. The results of experimental studies of uniformity of positive column of He-Cd$^+$ laser discharge are presented. It appears that the positive column is uniform in the discharge conditions typical of He-Cd$^+$ laser. However, a deviation from uniformity was monitored for another discharge conditions.

1. Introduction. The study of uniformity of positive column (PC) of He-metal laser discharges in tubes of cataphoretic type (Goldsborough [1], Sosnowski [2]) is attracting attention for the improvement of the design and performance of the He-metal lasers.

Up to date only one experimental work is known (Sosnowski [2]) concerning the study of uniformity of positive column of He-Cd$^+$ laser discharge. However, the results presented in [2] do not comprise the conditions typical of PC He-Cd$^+$ lasers. Besides, behaviour of only one parameter describing a distribution of cadmium atoms along the tube was reported, and no other information on behaviour of another important parameters of plasma of the positive column is given. The purpose of the present work was to examine experimentally the axial distribution of helium and cadmium atoms as well as the electric field in cataphoretic He-Cd$^+$ laser discharge tube in a wide range of discharge conditions, comprising also those typical of the lasing.

2. Experiment. The configuration of discharge tube used in this experiment was similar to that of Sosnowski [2]. The tube was 50 cm in length and 3 mm in diameter. The side-arm cadmium source was placed in the center of tube. All parts of the tube, except the small region of cadmium condensation, were put in the oven at a temperature of 350±7.5°C. The side-arm temperature controlled separately was stabilized to better than ±1/2°C. Along the tube 23 electric probes were placed at nearly equal distances. The length and diameter of each probe were 0.5 mm and 0.2 mm, respectively.

The experiment was made over the following range of parameters: the discharge current, 15—155 mA, helium pressure, 3 torr, cadmium vapour pressure, 10^{-5}

-10^{-2} torr (it corresponds to temperature of Cd source of about 150—270°C). The electric field was obtained from measurements of potential differences between probes. Several side-light intensities of He, Cd and Cd^+ spectral lines were measured as functions of distance along the discharge tube. For this purpose a monochrometer automatically drawn along the length of the tube was used, and signal from photomultiplier tube attached to it was recorded directly on an $x-y$ chart recorder. Because of the deposits formed on the inside walls of the discharge tube, the procedure of Sosnowski [2] was used for getting the correct distributions of side-light emission along the tube.

3. Results and discussion. The results of measurements can be divided into two groups.

The first group comprises the results obtained for a temperature of Cd source up to 230°C which is the upper limit of lasing conditions at 441.6 nm (Mizeraczyk [3]). Typical results of measurements of the distribution of 477.9 nm Cd side-light

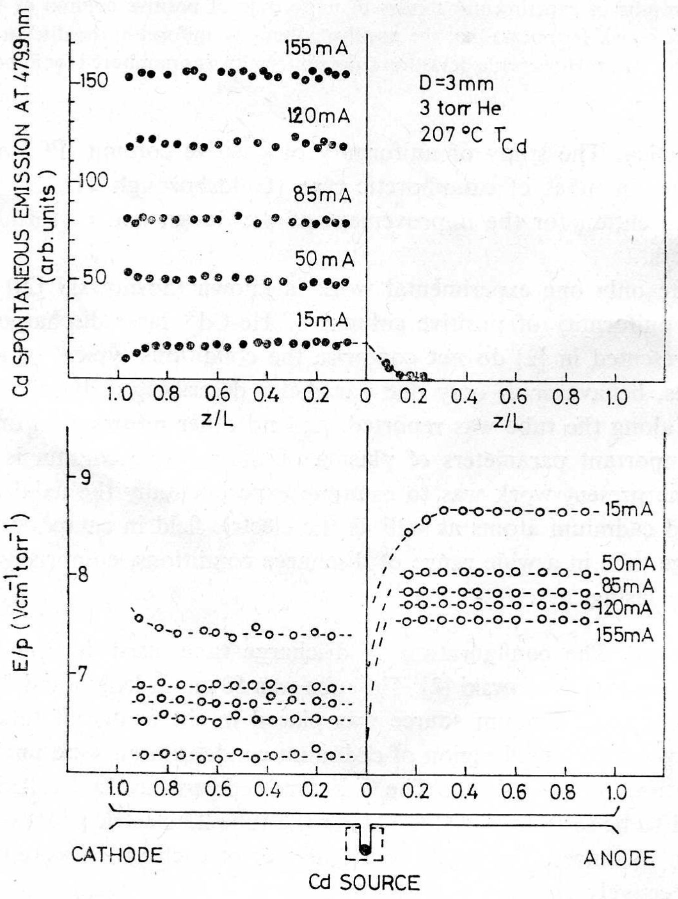

Fig. 1. The variations of 479.9 nm Cd sidelight intensity and reduced electric field E/p along the cataphoretic He-Cd^+ laser discharge tube for various currents, at a temperature of Cd source typical of laser conditions (L — distance between Cd source and electrode, z — distance from Cd source)

intensity, used as an indicator of Cd atom density (Sosnowski [2]), and reduced electric field E/p along the tube for these conditions are presented in Fig. 1. It is seen that both the distributions are uniform in the Cd source-cathode region of the discharge tube, except probably for small parts adjointed to the cathode and Cd source. Unfortunately, the measurements in these parts of the tube were not done because of technical difficulties concerning the construction of the tube and ovens. Similar uniform distributions were monitored for another spectral lines measured, i.e. for 388.9, 471.3, 492.1, 501.6, 504.7 nm He and 441.6 nm Cd^+ lines. Small deviation from uniformity was observed for the case of current of 15 mA. For this current there was monitored small intensity of 477.9 nm Cd line in the Cd source-anode region of the tube. It proves the presence of Cd atoms in this region of the tube at low currents. The increase of intensity of 477.9 nm Cd line with the distance from Cd source as the current is increased, observed by Sosnowski [2], was never observed in the present experiment.

For a Cd source temperature higher than about 230°C two phenomena were observed. At higher current, i.e. above of about 100 mA the steady and moving strations (Oleson and Cooper [4]) appeared, whereas at low currents a strong non-uniformity of the positive column, especially in Cd source-anode region, was monitored (Fig. 2). The presence of steady and moving strations in the discharge can be

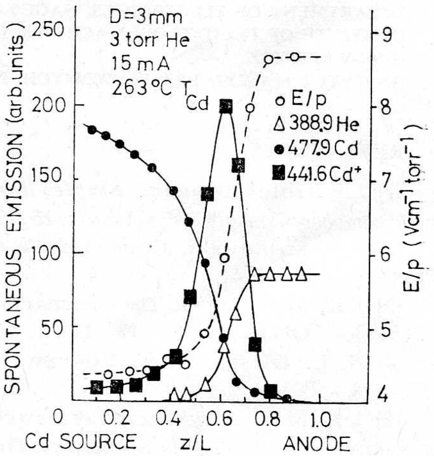

Fig. 2. Graph illustrating the nonuniformity of positive column of He-Cd discharge at low current and high Cd vapour pressure (scale for intensities of 388.9 and 441.6 nm lines is enlarged 2 and 10 times, respectively)

explained by a comparatively high degree of ionization of Cd component of the binary mixture due to high current and high Cd vapour pressure (Mizeraczyk *et al.* [5]). A comparatively low degree of ionization of the mixture at low currents as well as high Cd vapour pressure reduce the transport of cadmium to the cathode caused by cataphoresis, resulting finally in the nonuniformity of the He-Cd positive column.

Fig. 2 presents also a space visualization of Penning effect, which is the dominant process of excitation of upper 441.6 nm Cd^+ laser level (Silfvast [6]). According to it an intensity of spontaneous-emission sidelight at 441.6 nm should follow the behaviour of the product $M_T N_{Cd}$, where M_T is the He triplet metastable density and N_{Cd} is denisty of Cd atoms. In present experiment the behaviours of M_T and N_{Cd} were indicated by intensities of 388.9 nm He (Willgoss and Thomas [7]) and 479.9 nm Cd lines, respectively. It can be seen from Fig. 2 that the measured 441.6 nm spontaneous-emission sidelight follows the behaviour of the product $M_T N_{Cd}$ along the tube, showing the pronounced maximum.

Summarizing, for conditions typical of PC He-Cd$^+$ lasers (discharge current higher than 100 mA, temperature of Cd source up to about 230°C) the positive column of He-Cd glow discharge in cataphoretic type tube is uniform in both regions of the tube: Cd source-anode and Cd source-cathode, showing the drops at the Cd source and at the ends of the tube. From the practical point of view it means that uniform distributions of He and Cd atoms along the active part of tube, needed for effective laser action, can be obtained. For lower currents and higher Cd source temperature, beyond the range of the lasing conditions, the deviation from uniformity appears. Such behaviour of positive column seems to be very interesting for study of various fundamental processes occurring in He-Cd plasma.

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Ю. К. Мизерачик, Ю. Зиеманн, **Экспериментальное исследования однородности положительного столба разряда He-Cd$^+$ лазера**

Содержание. В работе представлено результаты экспериментального исследования однородности положительного столба разряда He-Cd$^+$ лазера. Показалось, что положительный столб является однородным в типичных условиях работы He-Cd$^+$ лазера. Отступления от однородности происходят для других условий разряда.