Absorption of the 441.6 nm He-Cd$^+$ laser line in a He-Cd positive column utilized in cataphoretic confinement

J. Mizeraczyk,[a] G. Jakob, E. Schmidt, and J. Mentel
Ruhr-Universität Bochum, Department of Electrical Engineering, 4630 Bochum 1, Universitätsstrasse 150, Germany

(Received 24 July 1992; accepted for publication 8 February 1993)

The experimental investigation showed that the absorption of the 441.6 nm He-Cd$^+$ laser line by the He-Cd positive column in the cataphoretic confinement sections used in hollow-cathode discharge He-Cd$^+$ lasers is relatively low ($\sim$0.1% per a few-cm-long He-Cd positive column). Such a low absorption should not decrease the 441.6 nm output power of the hollow-cathode discharge He-Cd$^+$ lasers more than a few percent. Estimates show that the Cd_2^* molecules may be responsible for this absorption.

I. INTRODUCTION

The confinement of Cd vapor to the excitation section of the discharge tube is a current technology problem of hollow-cathode discharge (HCD) He-Cd$^+$ lasers which belong to a laser group generating the so-called white-light laser beams, i.e., consisting of the three fundamental spectral lines: blue, green, and red, emitted simultaneously (Fujii, Takahashi, and Asami[1]). In the case of the HCD He-Cd$^+$ lasers these lines are 441.6, 533.7, 537.8, 635.5, and 636.0 nm. The way of realizing the Cd vapor confinement in the HCD He-Cd$^+$ lasers, originally introduced by Hernquist[2,3] for positive column (PC) He-Cd$^+$ lasers, is schematically shown in Fig. 1. In the method presented in Fig. 1 the confinement of Cd vapor to the laser excitation section is due to cataphoretic action (Laška[4] and Chanin[5]) occurring in the so-called PC confinement sections. Although there exists a controversy regarding the efficiency of the Cd particles' cataphoretic confinement to the laser excitation section, the cataphoretic confinement, even if not perfect, is experimentally proved as very effective (Mizeraczyk, Carlsson, and Hård[6]).

However, the cataphoretic confinement sections on the axis of the HCD He-Cd$^+$ lasers may contribute to absorptions of the generated laser lines and thus influence the output powers of the lasers. It appears that the positive column built up in the cataphoretic confinement section is divided into three parts (Mizeraczyk, Carlsson, and Hård[6]): (i) the Cd-like discharge region, located near the excitation section, in which the Cd atom density decreases linearly from the excitation section towards the anode; (ii) the transition region, in which the Cd atom density decreases quasiexponentially; (iii) and the He-like discharge region, adjacent to the anode, which seems to be free from Cd atoms.

A side-light observation of the Cd-like discharge region showed that this part of the confinement section emits broad spectral bands (Fig. 2), presumably due to the presence of molecular Cd particles (Cd_2, Cd_3, and Cd_2^+). The presence of the molecular Cd particles is highly probable in the Cd-like discharge region of the cataphoretic confinement section because of a relatively high density of Cd atoms ($\sim 10^{15}$ cm^{-3}, which is much higher than the Cd density typical of the PC He-Cd$^+$ lasers, being equal to about 1.5×10^{13} cm^{-3}). In the case of Cd_2 molecules, strong broadband absorptions between the $^3\Pi_g$ metastable state and the bound $^3\Pi_u$ charge-transfer state, as well as weaker but still significant broadband absorptions between the $^3\Sigma_u^+$ state and the repulsive $^3\Sigma_g^+$ state are predicted in the vicinity of 470 nm (Stevens[7]). Therefore, the absorption of the 441.6 nm He-Cd$^+$ laser line may be expected in the cataphoretic confinement sections.

In this article an experimental investigation of the absorption of the 441.6 nm He-Cd$^+$ laser line by the He-Cd positive columns built up in the cataphoretic confinement sections used in the HCD He-Cd$^+$ lasers is presented.

II. EXPERIMENT

A schematic of the He-Cd discharge tube used as an absorption cell in this experiment is shown in Fig. 3. The tube consisted of the two anodes, the cathode, the two capillary PC sections located between each anode and the cathode, and a Cd source. Each of the capillary PC sections, in which the absorption was to be investigated, was made of an 11-cm-long fused silica tube with an inner diameter of 3 mm. The capillary PC tubes were separated from each other by a distance of 3 mm, which enabled Cd vapor to enter into both capillary positive columns. The capillary PC sections were placed in a fused silica cylinder so that Cd vapor could reach the anode parts of the discharge tube only through both capillaries. The discharge tube was terminated with quartz Brewster windows fused to the tube endings.

Separate ovens were provided for the cathode, the Cd source and the capillary PC sections so that their temperatures could be controlled independently. The temperatures of the cathode and capillary PC sections were always kept at 663 K, which was well above the Cd source temperature. This prevented condensation of Cd atoms outside the Cd source.

The discharge tube and its parts were highly cleaned before using them in the experiment. Prior to placing the

[a]On leave from the Institue of Fluid-Flow Machines, Polish Academy of Sciences, 80952 Gdansk, Fiszera 14, Poland.

