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Comparison of Radial Helium Emission Line Profiles in Transverse and Longitudinal Hollow Cathode Discharges

J. Bergmann (a), J. Konieczka (b), J. Mizeraczyk (b), M. Schubert (a)

(a) Physico-Technical Institute, O-6900 Jena, FRG;
(b) Institute of Fluid-Flow Machines, Polish Academy of Sciences, 80-925 Gdansk-Wrzeszcz

Abstract

Results of measurements of the radial distributions of intensities of the He I and He II spectral lines emitted by the transverse and longitudinal hollow cathode discharges direct current excited are presented. The results show that both hollow cathode discharges exhibit different excitation efficiency of the spectral lines. The metastable level $2s^3S$ seems to be important for excitation of He I emission lines.

1. Introduction

The hollow cathode discharge (HCD) is used as an efficient excitation source for noble gas and He (or Ne)-metal vapour lasers (e.g. [1]). Recently the HCD has been used for generation of white-light laser radiation (simultaneous emission of the three fundamental colours: red, green and blue) in a He–Cd vapour mixture [2–7]. Such a laser could easily find application in quickly developing new techniques of image and information processing, of medical inspection and of measurement. However, the still insufficient state of understanding of physical phenomena in the HCD and the technological difficulties (cathode material sputtering, nonuniform metal vapour distribution) are the main obstacles hampering development of HCD lasers.

Hollow cathodes of different geometric forms and different arrangement with respect to the anodes were used for constructions of HCD lasers. It was shown, however, that the geometric configurations of hollow cathodes are not equivalent with regard to the efficiency of laser state excitations [3]. This mainly concerns media for which a relatively low excitation current is sufficient, as for example for a mixture of He and Cd used for white light laser generation.

The reason of the influence of the HCD geometry upon the efficiency of the laser line excitation has been extensively searched [8–10]. Investigations in anode-hollow cathode segments of different geometry showed that the existence of two kinds of discharges, namely the transverse discharge (TD) and the longitudinal discharge (LD) are the cause of different electrical and optical properties. Into the group of hollow cathodes with transverse discharge should be included all those cathodes in which the motion of the electric carriers occurs in the direction transverse to the axis of the cathode (Fig. 1a). In a hollow cathode with a longitudinal discharge the anode is located in such a manner that electrons leaving the cathode surface finally have to move along the cathode axis (Fig. 1b).

The electrical differences between both types of hollow cathode discharges, the TD and LD, have been sufficiently enlightened [8–10]. On the other hand, the optical properties of both discharges can be hardly compared because of lack of data. In particular, more data on radial distribution of optical properties of both discharges are needed for understanding and improving the HCD lasers.

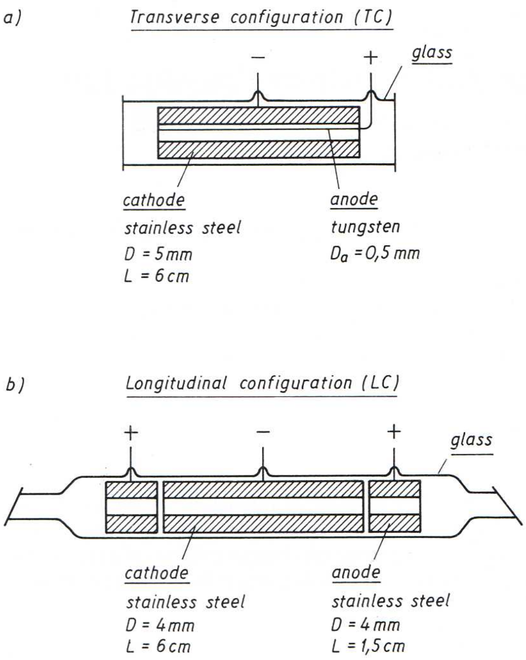

Fig. 1. Electrode configurations used for radial profile measurements in hollow cathode discharges (*D*-diameter, *L*-length).

The aim of this work was to compare the optical properties of the d.c.-excited hollow cathode TD and LD produced in helium under conditions close to those typical for He – Cd^+ laser operation. The data existing in the literature [11 – 14] are not sufficient to be used for the comparison because they concern quite different discharge conditions (pulsed or gas flow regime). The investigations concerned measurements of the radial distributions of intensities of He I and He II emission lines.

2. Experiment

The investigations were carried out using two HCD tubes the electrode configuration of which made it possible to form the TD and LD. The geometry of these both configurations (transverse: TC, longitudinal: LC) is shown in Fig. 1. The cathodes were made of vacuum outheated stainless steel. The discharges were excited with a current stabilized d.c.-voltage power supply. Ballast resistors of a few kΩ were used. The maximum discharge current was 150 mA. Because the diameters of the cathodes differ, for an equal mean current density the discharge current of 75 mA in the TC corresponds to a discharge current of about 60 mA in the LC. The He pressure ranged from 5 to 33 hPa. The sustaining voltage, higher in the case of the TC, lay between 170 and 300 V (Fig. 2). The voltage of 170 V at low discharge current corresponds to the normal cathode fall voltage which seems to be equal in both cases.