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# The performance of the hollow-cathode discharge continuous-wave multicolour He–$Cd^+$ laser

**J Mizeraczyk†, N Reich‡, J Mentel‡ and E Schmidt‡**

† Institute of Fluid Flow Machinery, Polish Academy of Sciences, PL-80952 Gdańsk, Fiszera 14, Poland
‡ Allgemeine Elektrotechnik und Elektrooptik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

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**Abstract.** We report on the performance of a hollow-cathode discharge continuous wave He–$Cd^+$ laser module, which is capable of simultaneously delivering stable, milliwatt output power at the three primary spectral lines: blue ($\lambda = 441.6$ nm), green ($\lambda = 533.7$ and 537.8 nm), and red ($\lambda = 635.5$ and 636.0 nm). In particular, the laser output characteristics for single- and multi-line operation and the power interaction between the laser lines are presented. The results show that the most efficient simultaneous laser oscillations at the red, green and blue lines occur for the He pressure (8 mbar at an inner diameter of the hollow cathode of 4 mm) at which the hollow-cathode effect is strongest. We find strong power interaction between the green and red lines, showing experimentally that, apart from the already known increase in the He–$Cd^+$ laser output power in the green owing to the radiative cascade transitions in the red, also the red lines gain in their output power under simultaneous operation with the green lines, which de-populate the lower laser levels of the red transitions. Under some conditions the de-population of the lower laser levels of the red transitions by the green lines' oscillations can be the dominant mechanism for the build-up of the population inversion between the upper and lower levels of the red transitions.

## 1. Introduction

Since its first introduction (Karabut *et al* 1969, Sugawara and Tokiwa 1970, Sugawara *et al* 1970, Schuebel 1970a, b) the hollow-cathode discharge (HCD) He–$Cd^+$ laser has become a very promising candidate for a multicolour laser system. From the 11 laser lines generated under CW operation by the HCD He–$Cd^+$ laser in the spectral range 325.0–887.8 nm (Willett 1974) the simultaneously generated blue ($\lambda = 441.6$ nm), green ($\lambda = 533.7$ and 537.8 nm) and red ($\lambda = 635.5$ and 636.0 nm) lines are of interest for colour information processing technology. The wavelengths of these lines are close to those of the three ideal primary spectral lines ($\lambda = 450$, 540 and 610 nm (Thornton 1971)). Owing to this, the colour of the HCD He–$Cd^+$ laser beam can be varied over a wide range, including white colour, after a proper mixing of the red, green and blue laser lines. Despite the permanent demand for such a multicolour laser, there is at present no multicolour HCD He–$Cd^+$ laser device available on the laser market, mainly because of the problems with manufacture, stability and maintenance of the HCD laser systems.

We have recently reported the design features of a 10 cm active length HCD CW multicolour He–$Cd^+$ laser module, which, owing to the particular cathode design, laser tube conditioning and thermal instability precaution employed, is capable of simultaneously delivering stable, milliwatt power output at the three primary spectral lines (Mizeraczyk *et al* 1994). Owing to this stable operation of the laser, we were able to investigate the output power characteristics of each laser line reliably in single- or multi-line operation using a birefringent filter (Mentel *et al* 1992). As a result, some interesting characteristics of the HCD He–$Cd^+$ laser operation, corresponding to power interaction of the laser lines, were obtained. These characteristics showed some correspondence between the performances of the HCD He–$Cd^+$ laser and a He–$Cd^+$ laser excited transversely by capacitively coupled radio-frequency (CCRF) power (Reich *et al* 1994), and therefore they are also of importance for the practical development of He–$Cd^+$ laser systems excited by CCRF power. In the near future, the CCRF-excited He–metal vapour ion lasers may become competitors to those excited in the HCDs.

## 2. Experiment

The detailed design of the HCD CW multicolour He–$Cd^+$

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