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Infrared laser properties of sputtered He – Cu mixtures excited by radio-frequency and hollow-cathode discharges

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Laser action on Cu II $\lambda = 780.8$ nm line in sputtered He – Cu mixtures excited by radio-frequency discharge is reported. The threshold power ot the laser operation has been as low as 20W per unit length of the discharge. Small-signal gain measured in media excited by a conventional hollow cathode and an RF discharge shows close resemblance for both kind of excitation. For similar cross-sections of the discharge the gain coefficients are similar at the same linear densities of the discharge power. For the RF excitation the gain coefficient exceeding 20%/m has been obtained at 240 W/cm.

Key words: RF, hollow-cathode discharge, metal ion laser, sputtering, laser gain

1. INTRODUCTION

For more than two decades laser transitions have been detected in discharges produced in several metal vapour-noble gas mixtures, [1 – 2]. In this kind of lasers population inversion between excited states of singly ionised metal ions is achieved

by the thermal energy charge- transfer reaction between metal atoms and ground state noble gas ions. The charge-transfer reaction occurs effectively in a hollow cathode discharge, (HCD) where large numbers of fast electrons oscillating between the opposite walls of the cathode produce a high density of the noble (buffer) gas ions and the necessary density of metal atoms is obtained by cathode sputtering. Such metals as Ag, Au and Cu which cannot be easily evaporated are efficiently sputtered by ion bombardment of the cathode walls. For each of them, using He or Ne as the buffer gas, strong laser lines covering the spectral range from 220 nm to near infra-red have been reported, [3–5]. Despite many attempts the efficient and cheap UV HCD lasers operating in CW or long pulse mode have not yet been constructed, mainly due to a discharge instability, so called arcing. An alternative to the HCD excitation of the sputtered metal vapour-noble gas systems is a radio-frequency, (RF) discharge. The RF excitation widely used in modern waveguide CO_2 lasers, has been successfully applied to other noble gas-metal vapour and noble gas mixture systems like $He-Cd^+$, $He-Se^+$ and $He-Kr^+$ [6, 7]. Both the HCD and RF discharges show much similarity in assuring very effective ionisation within the discharge volume. However, the later is more advantageous in producing stable and uniform discharge plasma. The laser oscillations on an infra-red line in a sputtered He–Cu mixture excited by the RF discharge were first reported in [8], but no further attempts were made to optimise the discharge and generation conditions.

In this paper we present the results of our study of lasing features, i.e. laser action and unsaturated gain in sputtered He–Cu mixtures excited by capacitively coupled radio-frequency (CCRF) and conventional hollow-cathode discharges. Our measurements have been carried out for the strongest Cu II laser line, $\lambda = 780.8$ nm. The small-signal gain obtained for the RF excitation is compared with the gain measured for two types of hollow cathodes with similar discharge cross-sections areas.

The ultimate aim of our researches is collecting the necessary data for the future investigations of UV operating lasers excited by the RF discharge.

2. EXPERIMENTAL

We used two different configurations of discharge tubes to investigate the laser action in sputtered He–Cu mixtures excited by the RF discharge. The first one was provided with a pair of oxygen-free copper electrodes in the form of half-solid cylinders placed parallel to each other and 3 mm apart. The length of each electyrode was 40 cm. The cylindrical parts of the electrodes were enveloped with fused silica glass half-cylinders to prevent the RF discharge outside the volume between the flat surfaces of the electrodes. The cross-section of the discharge gap was 3×12 mm, as it can be seen in Fig. 1a. In the second laser tube the 20 cm long