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Comparison of the output power of copper halide lasers versus buffer gas pressure and frequency

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ABSTRACT

In this work, an iodide copper vapor laser (CuI) has been designed and fabricated. The effect of different operational parameters such as frequency and buffer gas pressure on output power laser have been investigated to determine the optimal condition of frequency and neon gas pressure. Based on experimental results, the maximum output power of about 0.5W is obtained at 16 kHz of frequency and 30 torr of Ne gas pressure. Moreover the experimental results of CuI laser have been compared to the similar data for the other halide copper lasers such as CuBr and CuCl. The output power of CuI laser is less than that of others. The optimum frequency of lasers have different values, but the optimum gas pressures are the nearly same for three lasers, at the same conditions.

Key words: Copper halide laser, Output power, Frequency, Buffer gas pressure.

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INTRODUCTION

Considerable attention has been given to lasers utilizing the vapors of different compounds of copper. The application for the copper laser at two principal visible outputs of 510.6 and 578.2-nm includes high repetition rate pumping of tunable dye lasers, high-speed flash photography, large image projection television and material processing. A technique for using copper halide as the source of copper atoms in a copper vapor laser (CVL) was first reported in 1973. The operating temperature of copper halide lasers (400-600°C) depends on the vapor pressure and type of the compounds and is much lower than that of the pure CVL(1550-1700°C).

This advantage yields a significantly shorter warm-up time for the halide laser, which is important to reduce downtime in commercial applications (Rahimi et al., 2011; Little 1991; Petrash 1988; Walter et al., 1966; Lewis, 1991). Halide lasers such as copper bromide (CuBr), copper chloride (CuCl) and copper iodide (CuI) lasers are necessary to be heated to 400, 500, 600 °C, respectively. In this work, a CuI laser with 19mm of bore has been designed and fabricated to study the behavior of laser output power versus pressure of neon buffer gas and frequency. The experimental results have been compared to the experimental results on CuBr and CuCl lasers.

MATERIALS AND METHODS

The laser schematic diagram of discharge tube is shown in Fig.1. The discharge is contained within a quartz tube having an internal diameter of 19 mm between electrodes which are separated by 49cm. The total length of the laser tube, including the extended windows region, is 90cm. Hollow cylindrical water–cooled copper electrodes have been used. Silicon rubber o-ring ensures adequate vacuum seals.

One heated side-arm reservoir of high purity CuI powder, which is located at the middle of the tube, is used to seed the discharge zone with CuI vapor. The temperature of the reservoir is typically 600°C, while the discharge channel is held at a slightly elevated temperature, so that the side reservoir temperature controls the vapor pressure of CuI in the main tube. The laser cavity is formed by a flat dielectric coated high reflector at both laser wavelengths, and an uncoated quartz flat act as an output coupler.

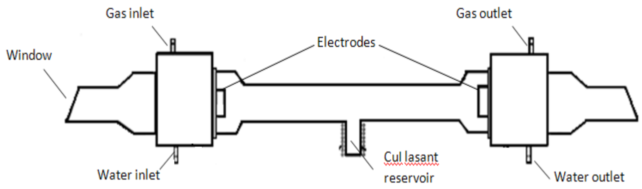

Fig.1. Schematic layout of CuI laser.

Neon is employed as the buffer gas. The laser tube is coupled to the standard driven circuit as shown in Fig.2. The gas on the tube is excited by the discharge of a 1.65-nF main capacitor (C_s) through the TGI1-1000/25 thyratron, which is cooled with air. A 1.1-nF peaking capacitor (C_p) is connected between the tube electrodes as well as the 100µH inductance (L_b). The laser output is measured by a Molectron™ PM500D power meter.

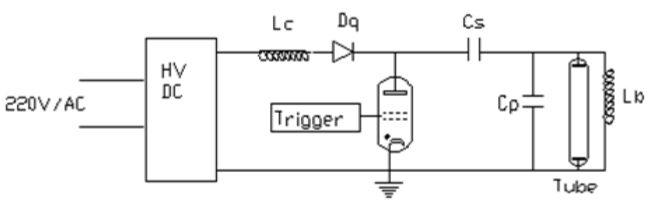

Fig. 2. Schematic layout of standard circuit of CuI laser:

$$c_p = 1.1nF, c_s = 1.65nF, L_c = 130mH, L_b = 100\mu H$$

RESULT AND DISCUSION

At first, the output power of the CuI-Ne laser has been measured versus various parameters such as buffer gas pressure, electrical input power and repetition frequency to obtain the optimal condition of output power. It is determined to be 0.5W at about 30 torr of neon buffer gas pressure, 3kV of input voltage and 16 kHz of frequency. The vapor pressure of CuI is varied from 0.2 to 0.3 torr by alteration of the temperature of the CuI reservoir heaters from 550 to 600°C. The temperature of the laser tube was about 40 degrees higher than that of the CuI reservoir. Fig.3. depicts the output power of CuI laser versus the neon pressure at fixed frequency of 16 kHz and input power of 635W. As can be seen, the maximum power could be achieved at pressure of 30 torr.

When the pressure of buffer gas is increased, the rate of elastic collisions of electrons with gas atoms is increased, so.

In this treatment the temperature of electrons is closed to the optimum temperature, where the population inversion is highest. The increase in output power continues to optimal pressure of 30 torr. At higher pressure, it decreases mainly due to the inelastic electron-atoms collisions, which subsequently causes the electron temperature to drop such that a changeover of the pumping rates occurs and the output eventually ceases to oscillate.

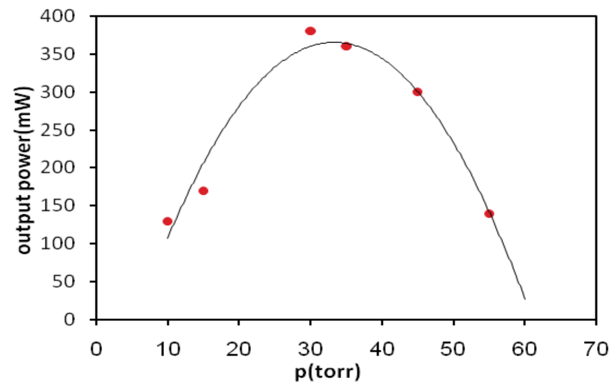

Fig .3. Average laser output power versus buffer gas pressure.

The behavior of output power of CuI laser versus repetition frequency is shown in Fig.4. The gas pressure and electrical input power are kept constant at 30 torr and 635W, respectively. As can be seen, the output power has fluctuations. The minima represent a significant output power drop attributed to the acoustic resonance of the laser tube (Zoghi, et al, 2009; khorasani et al, 2008). The acoustic wave changes the density of the medium in the vicinity of the resonator axis, and this leads to a change in the lasing condition. The repetition frequency has been changed between 10-20 kHz. The optimum repetition frequency is inversely proportional to the tube bore and the approximate relationship between them is f (opt) = 300/d were f is in kilohertz and d is the tube diameter in millimeters (Lewis, 1991). For this laser, the optimum repetition frequency of 15.8 kHz has been calculated, as can be seen from Fig.4, the optimum frequency of 16 kHz has been obtained.

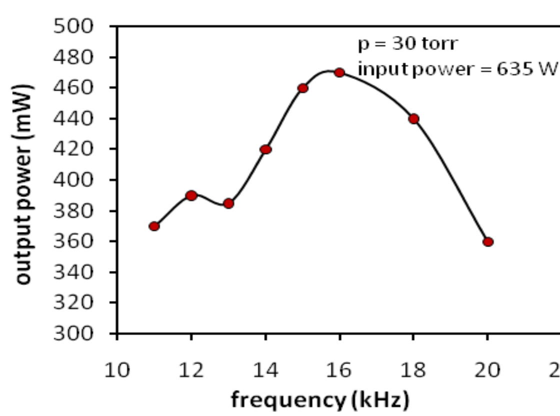

Fig .4. Laser output power versus frequency.

The various experiments have been carried out on CuBr and CuCl lasers and their results are compared with CuI laser. The dependence of average output power on the neon gas pressure and frequency are plotted in Figs. 5 and 6, respectively.

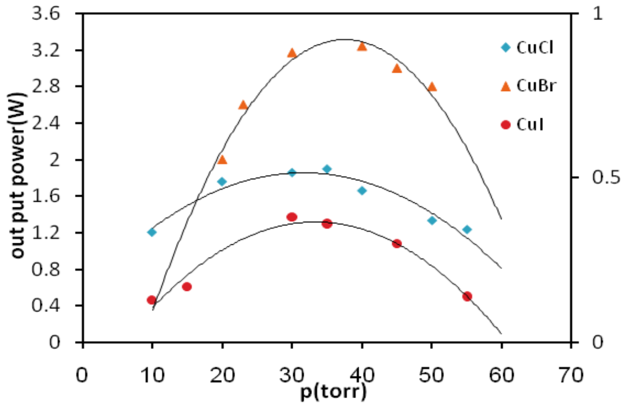

Fig. 5. Laser output power versus neon buffer gas ressure for CuI, CuBr and CuCl as lasants. The left axis is related to CuCl and CuBr lasers and the right one is related to CuI laser.

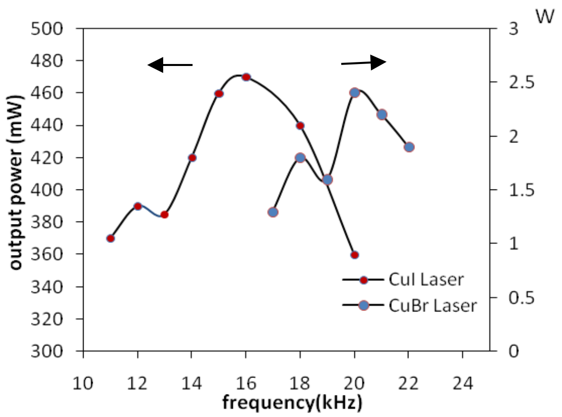

Fig. 6. Laser output power versus frequency for CuI and CuBr as lasants.

The behavior of output powers versus Ne gas pressure are the same in all lasers, and the optimum gas pressures are achieved in the range of 30~40 torr. The similar observations are reported for longitudinally excited double- pulse copper halide lasers (Gabay et al, 1977). The output power of CuBr and CuCl are greater than that of CuI laser. The fluctuations of output power versus frequency at both the lasers, CuI and CuBr lasers have some maxima and minima that are due to acoustic resonance phenomenon. As can be seen, the optimum frequencies are different for lasers, such that, the optimum frequency of 16 kHz and about 20 kHz are obtained for CuI and CuBr lasers, respectively.

CONCLUSION

A CuI laser with length of 49cm and diameter of 19mm has been fabricated, and some experiments have been carried out. The maximum output power of about 0.5W is obtained at Ne gas pressure of 30 torr and frequency of 16 kHz. The results have been compared with previous work on other copper halide lasers in the laboratory.

The dependence of the output powers on frequency has the same behavior in halide lasers family. The output power of lasers has been increased with frequency at first, and then, some maxima and minima have been observed due to acoustic resonance phenomenon like pure CVLs. The output power of CuCl laser is more than that of others, and the output power of CuI laser is less than that of CuBr and CuCl lasers at same conditions. Meanwhile, the optimum frequency of lasers are different, but the optimum gas pressure are the nearly same with identical tubes.

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