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Investigation of operational parameters on copper bromide laser output power

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ABSTRACT

In this work, a copper bromide laser with an active medium length of 58 cm and an inner diameter of 20 mm designed and constructed. He and Ne used as buffer gases. The effect of reservoir temperature, He and Ne buffer gas pressure, frequency and electrical input power on the output power investigated. The result of experiments shows that an optimum laser efficiency obtained at the electrical input power of 2.1kW and corresponding operational temperature of 510 ^{oC}. The maximum output powers, 4 and 6 W, with use of He and Ne buffer gases, were determined at pressures 11 and 24 torr, respectively.

Keywords: Copper Bromide Laser, operational parameter, He and Ne buffer gas

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INTRODUCTION

One of the most interesting laser source in visible region are copper vapour lasers (CVL's). Copper vapour lasers work at high temperature. Hence, the halide lasers produced to overcome the problems of CVL's. The operating temperature of halide lasers (400- 600 ^oC) depend on the vapour pressure and type of the compounds and is about 500 ^oC for copper bromide lasers(CBLs) (Aeinehvand, Behrouzinia, Salem, Elahei, & Khorasani, 2017; Dehghani, Khorasani, Sajad, Salehinia, & Behrouzinia, 2011; Gabay, Smilanski, Levin, & Erez, 1977; Lima, Behrouzinia, & Khorasani, 2018, 2019; Lima et al., 2017; Little, 1999; Petrash, 1988) which is much lower than of the pure CVL's (1550- 1700 ^oC) (Ashtari, Behrouzinia, Sajad, & Zand, 2011; Behrouzinia, Namdar, Zand, Barry, & Hojabri, 2006; Kazaryan, Petrash, & Trofimov, 1980; Nerheim, 1977). The other advantages of halide lasers are reduction of warm-up time for laser oscillation, which is important in commercial applications, higher pulse repetition frequency, higher wall-plug efficiency and higher beam quality (D. Astadjov et al., 1997; D. N. Astadjov, Stoychev, Dixit, Nakhe, & Sabotinov, 2005).
The buffer gas in a CBL tube is employed to increase the output power and improve the laser performance (Behrouzinia, Khorasani, & Kazemi, 2013; Zand & Khorasani, 2014). It is necessary to produce the population inversion mechanism via energy transfer of the gas, ions or electrons to the metal atoms

(Behrouzinia, Khorasani, & Farahmandjou, 2016). The addition of a buffer gas allows the impedance of the discharge tube to increase, thus leading improving impedance matching by the excitation circuit (Little, 1999). The best buffer gas to use, among the He, Ne, Ar, Kr, Xe gases, is Ne, which provides higher output power at higher gas pressure (Lesnoĭ, 1984). The next best buffer gas to use, is He, which gives longer and lower discharge current pulses (Little, 1999).

EXPERIMENTAL SETUP

In this paper, a CuBr laser consisted of a cylindrical tube of 58 cm active length and 20 mm inner diameter has been designed and constructed to investigate the output power behaviour versus operating temperature, electrical input power, frequency and pressure of *He* and *Ne* buffer gases. The discharge tube of the CBL is made of quartz. Hollow cylindrical water-cooled copper electrodes have been utilized for discharge. One heated side arm reservoir of high purity CuBr powder, which is located at the middle of the tube, is used to seed the discharge zone with CuBr vapour. A couple of flat-flat resonators with reflectivity of 98% and 4% are usually considered as the back and front mirrors, respectively. The laser discharge tube shown schematically in Fig.1.

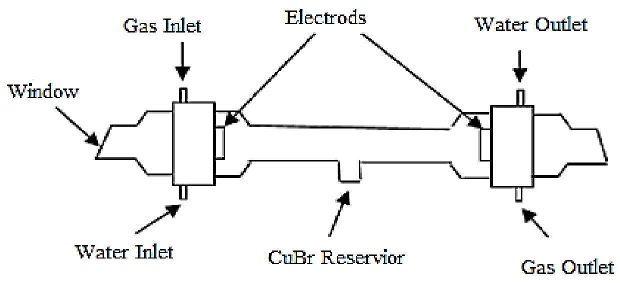

Fig. 1. Schematic layout of CuBr laser.

It is coupled to the standard driven circuit as shown in Fig. 2.

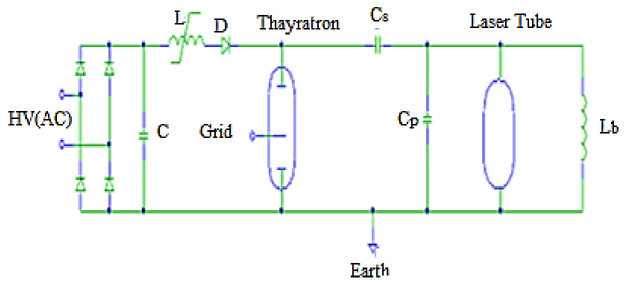

Fig. 2. Schematic representation of standard circuit of CuBr laser. C_p=0.47nF، C_s=1.65nF، L_b=100μH , L=150mH

The temperature of the reservoir is typically 500 ºC, while the discharge channel is held at a slightly elevated temperature. The gas in the tube is excited by the discharge of a 1.65 nf storage capacitor (Cs) through the TGI1_1000/25 Thyratron, which is cooled with air. A 0.47 nf peaking capacitor (Cp) is connected between the tube electrodes as well as the 100μH inductance (L_b). The laser output power is measured by a Molectron ^{TM}PM500D power meter.

RESULTS AND DISCUSSION

Fig.3. shows the behaviour of the output power of CBL versus tube wall temperature at fixed optimum He buffer gas pressure of 11 torr and optimum frequency of 20 kHz.

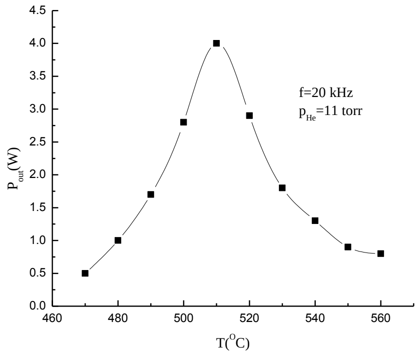

Fig. 3. Variation of p_{out} versus T.

As can be seen, the wall temperature of the tube increased from 470 to 560 ºC when the electrical input power increased from 1.8 to 2.2 kW, as indicated in figure 4.

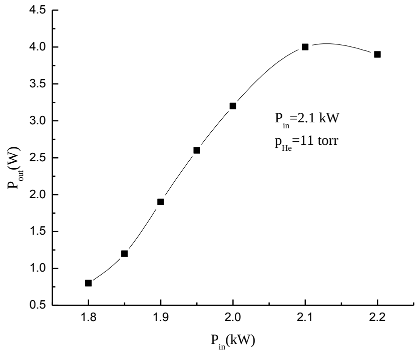

Fig. 4. Variation of p_{out} versus P_{in}

The maximum output power reached at wall temperature of 510 ºC, corresponding to the electrical input power of 2.1kW. According to figure 3 and 4, as the electrical input power is increases from 1.8 to 2.1 kW, the temperature inside the tube and then the density of copper atoms increases, which causes an increase to the upper laser level and then total output power of laser. When the electrical input power increases from 2.1 to 2.2 kW, the density of the CuBr molecules increases, which causes to decrease of electron temperature due to inelastic collisions and then the output power decreases.

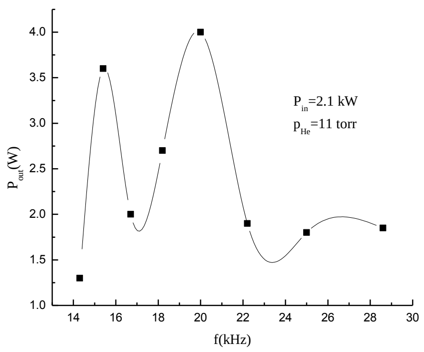

Fig. 5. Variation of P_{out} versus frequency

Fig.5. shows the dependency of output power of CBL on the repetition frequency. The electrical input power and He buffer gas pressure are kept constant at 2.1 kW and 11 torr, respectively. As can be seen from the figure, the variation of the output power relative to the frequency has oscillatory behaviour. The minimum represents the output power drop, which is related to the acoustic resonance of the laser tube (Khorasani, Salehinia, Behrouzinia, Sajad, & Parvizian, 2008; Zoghi et al., 2009). The repetition frequency has been changed between 14- 29 kHz.

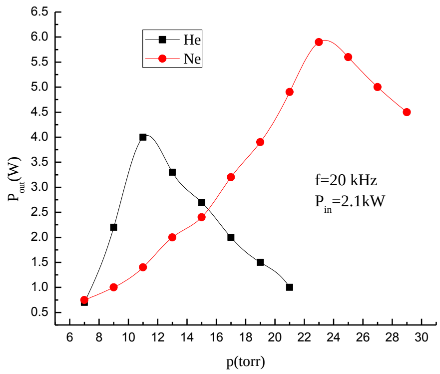

Fig. 6. Variation of CBL output power versus He and Ne buffer gas pressure

The variation of output power versus He and Ne gas pressure is depicted in Fig. 6 under the same conditions, i.e., the pulse repetition frequency is fixed at 20 kHz and the electrical input power is kept at 2.1 kW. It is indicated that the operational gas pressure intervals are different from each other. The pressure interval of He is approximately between 7 and 21 torr, while the pressure interval of pure Ne is wider than He. As it shown in Fig. 6, both gases show an optimum value for buffer gas pressure. The collision cross section of electrons and copper bromide molecules with He and Ne are different and therefore effect on laser output power. Maximum output power has been achieved at He and Ne gas pressure of 11 and 24 torr, respectively. Below these values, the increase in pressure improves the pumping of the upper laser level and above these values, the tube inductance is high, which results to instability of discharge and reduction of output power (Little, 1999). The current finding can be compared to the results of research completed by Dehghani et al. (2011), where the output power of 0.5 W was obtained at optimum Ne gas pressure of 30 torr, input electrical power of 635 W and 16 kHz of frequency. The range of operational pressure used in their research was between 10-60 torr.

CONCLUSION

A CuBr laser with active length of 58 cm and inner diameter of 20 mm has been designed and constructed, and the output power of the laser was studied in terms of the tube wall temperature, electrical input power and frequency. In addition, the output power behaviour was investigated in terms of He and Ne buffer gas pressure. The type of buffer gas has a strong influence on the output power of the CBL. The results indicate that the operating pressure range is dependent on the type of buffer gas. The maximum output power of 6 W is obtained at Ne buffer gas pressure of 24 torr, frequency of 20 kHz and electrical input power of 2.1 kW, while at the same conditions the maximum output power for He gas is obtained at 11 torr. It was found that using He buffer gas in CBLs can achieve higher efficiency and output power than Ne buffer gas at low pressure. The variation of output power versus frequency has been investigated. Some maxima and minima have been observed due to acoustic resonance phenomenon. An optimum electrical input power of 2.1 kW and a corresponding temperature of 510 ^{o}C were determined for the maximum output power.

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