Frequency Dependence of the Output Power of Copper Bromide Lasers in the Various Active Lengths

S. Mohammadpour Lima¹, S. Behrouzinia²*, K. Khorasani²

¹Department of Physics, Chalous branch, Islamic Azad University, Chalous, Iran
²Photonics and Quantum Technologies Research School, Nuclear Science and Technology Research School, PO Box 14399511-13, Tehran, Iran
sbehrouzi@aeoi.org.ir

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Abstract- Three copper bromide lasers with different active lengths of 28, 38 and 48cm, but the same inner diameter of 20 mm have been designed and constructed. Influence of frequency as an operational parameter on lasers output power has been investigated. Based on experimental results, the maximum output power of lasers, 1, 1.7 and 2.5W are obtained at frequency of 15.4 kHz using by 12 torr He buffer gas pressure in electrical input power of 1.4, 1.55 and 1.7 kW, respectively. The oscillatory behavior of the output power versus frequency have been observed using of He and Ne buffer gasses in our experimental results.

Key Words: Copper bromide laser, buffer gas, frequency, output power.

1. INTRODUCTION

Considerable attention has been given recently to lasers utilizing the vapors of different compounds of copper. A technique for using copper halide as the source of copper atoms was first reported in 1973 [1-3]. Copper Bromide self-terminating lasers (CBL) are the most powerful and efficient of the copper halide lasers in the visible spectrum. Their principal superiorities are the high beam quality, output power, pulse repetition frequency (PRF) and short pulse length [4]. The operating temperature of CBL can be reduced to around 500°C [5-10], due to volatile nature of CuBr molecules, as compared to pure copper vapor lasers (CVL) which must be operated in the interval of 1550–1700°C [11,12]. The lower operational temperature of the active medium of CBL is cause to utilize of materials within their limits of operation, simpler construction of tube and reduction of start-up time for laser oscillation from a cold start [13]. The other advantages of the CBL are higher PRF, higher wall-plug efficiency and a pseudo-Gaussian beam intensity profile that is better suited to many applications than the top-hat profile of the CVL [14,15]. These lasers have extensive range of applications such as scientific research in chemistry and physics for isotope separation, medical and medicine research and micro processing of materials in industry [16,17]. In this work, three cylindrical tubes of 20 mm inner diameter and different active lengths of 28, 38 and 48 cm are designed and constructed to investigate the behavior of laser output power versus frequency using of He and Ne buffer gasses. The experimental results indicate oscillatory behavior of output power for three lasers, like what happen for CVLs.

2. EXPERIMENTAL PROCEDURE

The laser discharge tube is shown schematically in Fig.1. The discharge is contained within a quartz tube having an internal diameter of 20 mm but different active lengths of 28, 38 and 48 cm. Two hollow cylindrical water-cooled copper electrodes have been utilized. Silicon rubber o-ring ensure adequate vacuum seals. One heated side arm reservoir of high purity CuBr powder is utilized to seed the discharge zone with CuBr vapor, which is placed at the middle of the tube. Reservoir temperature is mostly 500°C, while the discharge channel is maintained at a slightly elevated temperature, so that the side reservoir temperature controls the vapor pressure of CuBr in the main tube.

![Fig. 1: Schematic layout of CuBr laser tube.](image)

The laser cavity is organized by a flat dielectric coated with high reflectivity mirror ≥98% as a back mirror, and an uncoated quartz flat with reflectivity of ≥4% as the output coupler. The output power of the lasers is measured by a Molectron 150PM500D power meter. He and Ne are utilized as the buffer gasses. The He buffer gas pressure was kept at optimum value of 12 torr during the experiments. The laser tube is coupled to the standard charge – transfer circuits as indicated in Fig. 2. The gas inside the tube is excited by the discharge of a main capacitor (Cₛ) through the TGI1-1000/25 thyatron as a switching device, which is cooled with water and air. A peaking capacitor (Cₚ) and an inductance (lₒ) are connected between the tube electrodes. An electrical power source and its corresponding pulse generator have been utilized on laser heads. Around of laser tubes, a thick layer of thermal insulation was wrapped up. The tube was self-
discharge heated and its temperature was increased by increasing the input power. The laser warm-up time was about 10 minutes.

![Schematic representation of standard circuit of CBL.](image)

**Fig. 2:** Schematic representation of standard circuit of CBL. \( C_p = 0.47 \text{nF} \), \( C_s = 1.65 \text{nF} \), \( L_b = 100 \text{H} \), \( L = 150 \text{mH} \).

3. **RESULT AND DISCUSSION**

   At first, the optimum condition of output power of the CBL have been determined by varying the electrical input power, and buffer gas pressure. The output power of CBLs with active lengths of 28, 38 and 48 cm versus frequency have been investigated at an optimum He buffer gas pressure of 12 torr and optimum electrical input power of 1.4, 1.55 and 1.7 kW, respectively. The experimental results display almost identical oscillatory behavior, which are exhibited in Figs. 3-5, respectively. The electrical input power is calculated from the following equation, \( P_{in} = \frac{1}{2} C_s V_{CP}^2 f \). In order to have constant input power, the input voltage must be reduced by increasing the frequency. The output power of laser with active lengths of 28, 38 and 48 cm has some local maxima and minima in the frequency interval of 14-29 kHz. As seen from the figures, there is one optimum frequency that the output power gives the maximum. There are also some other frequencies that the output power has peaks, but lower than that of the optimum one. At the frequencies of 15.4, 18.2 and 22.5 kHz, output power reaches to the local maximum value so that at 15.4 kHz, the output power has the highest value. The highest value of \( P_{out} \) at frequency of 15.4 kHz are given 1, 1.7 and 2.5W for active lengths of 28, 38 and 48cm, respectively, and at other frequencies (18.2 and 22.5 kHz), \( P_{out} \) has the values lower than the first one. At these frequencies, especially at 15.4 kHz one, the optical resonance effect of the laser tube has occurred hence output power has increased. At the minimum points, the acoustic resonance of the laser tube has occurred and dominant, and the output power are decreased. The observed oscillations in this tube, due to the acoustic effects inside the tube, have also been observed in CVLs, before [18, 19].

![Output power versus frequency for laser with active length of 28 cm.](image)

**Fig. 3:** Output power versus frequency for laser with active length of 28 cm.

![Output power versus frequency for laser with active length of 38 cm.](image)

**Fig. 4:** Output power versus frequency for laser with active length of 38 cm.

![Output power versus frequency for laser with active length of 48 cm.](image)

**Fig. 5:** Output power versus frequency for laser with active length of 48 cm.

![Variation of \( P_{out} \) versus frequency with Ne buffer gas.](image)

**Fig. 6:** Variation of \( P_{out} \) versus frequency with Ne buffer gas.

In order to investigate the effect of buffer gas type on the laser output power behavior at different frequencies, the experiments has been repeated. Dependence of frequency on the output power of laser with active length of 38 cm at 12 torr of Ne buffer gas pressure and electrical input power of 1.55 kW is shown in Fig. 6. It is apparent from the figure that there is an oscillatory behavior in this tube, like the previous ones. The local maximum output powers of laser are obtained at the frequencies of 17.9, 23 and 26.9 kHz and the minimum output...
powers of laser are achieved at the frequencies of 15.2, 20 and 25 kHz. The maximum laser output power of 1.59W is obtained at frequency of 23 kHz. As can be seen from Fig. 6, the laser output power has a tendency to upraise by increasing of PRF while in the previous section test using of He buffer gas, the output power has a downward trend by increasing of PRF. The output power behavior is complicated by varying the operational frequency. The difference in the laser output power behavior using of He and Ne is due to this fact that the collision cross section of the electrons and CuBr molecules with these gasses is different and hence affect the gain and thus the output power of the laser.

The behavior of output power versus input electrical power at 12 torr buffer gas pressure and 15.4 kHz frequency for the laser with active length of 48 cm is shown in Fig.7.

![Graph showing output power versus input electrical power](image)

Fig. 7: Variation of $P_{\text{out}}$ versus $P_{\text{in}}$

By increasing the electrical input power, the temperature and subsequently the heat inside the tube increases, which increases the number of available copper atoms for excitation to the higher laser level. As a result, when the electrical input power is increases from 1.4 kW to about 1.6 kW, the output power of the laser also to be increases. After reaching the maximum value of 2.5W, by more increasing of the electrical input power, the electron inelastic collisions rate with copper bromide molecules increases, which leads to decreasing of the electron temperature and decreasing of the population inversion and consequently decreases output power.

4. CONCLUSION

Three CuBr lasers with different active length of 28, 38 and 48 cm but the same inner diameter has been designed and fabricated. The behavior of output power of the lasers versus frequency and buffer gas type have been investigated. By changing the frequency, fluctuations were observed in the output power. The local maxima and minima were observed in the frequency range of 14 to 29 kHz, which is related to the presence of acoustic resonances in the laser tube, just like what happen in CVLs. The maximum laser output power using of He buffer gas was obtained at a frequency of 15.4 kHz, while the maximum value of the power was obtained at a frequency of 23 kHz using of Ne. The optimum pressure for the two buffer gas He and Ne was also determined to be 12 torr. The collision cross section of electrons and copper bromide molecules with He and Ne are different and therefor effect on the laser output power.

REFERENCES


