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The optimum geometrical ratio in halide lasers

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ABSTRACT

Some halide lasers tubes with different volume were used to investigate the geometrical dependence of the output power of laser. An optimum length-to-bore ratio of about 30 was obtained, which gives maximum average output power of halide lasers. The relationship between maximum average output power and geometrical factors of lasers were deduced and compared by than that of copper vapour lasers. So, the straightforward relation was obtained for designing of halide lasers tubes.

Keywords: Bore, Halide lasers, Length, Output power

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INTRODUCTION

The halide lasers are developed to overcome the problems of pure metal copper vapor laser (CVL). The advantages of the halide lasers are: low temperature of operation which gives simpler construction of tube, reduction of start-up time for laser oscillation from cold start, higher pulse repetition frequency, higher wall-plug efficiency, and a pseudo-Gaussian beam intensity profile that is better suited for many applications than the top-hat profile of elemental CVL (Ashtari, Behrouzinia, Sajad, & Zand, 2011; Dehghani, Khorasani, Sajad, Salehinia, & Behrouzinia, 2011; Tiwari, Mishra, Khare, & Nakhe, 2014). One way to increasing of the output power from a single laser is either by increasing the active length or by increasing the cross-section, or bore of the active medium. However the values of these geometrical factors of tube are limited by some reasons. The cavity round-trip time is increases by increasing the length and therefore it reduces the yield of good beam quality output. On the other hand, increasing the tube bore requires an increase in resonator magnification and therefore power extraction from gain medium is reduced because of reduced feedback. The problems, which make a single laser with large Fresnel number not suitable for providing high power with good beam quality, are reported (Chang, 1994). The best alternative to obtain high power with good beam quality from halide lasers, as CVLs, is the use of the master oscillator and power amplifier configuration (Aeinehvand, Behrouzinia, Salem, Elahei, & Khorasani, 2017; S Behrouzinia, Sadighi-Bonabi, Parvin, & Zand, 2004; Saeid Behrouzinia, Sadighi, & Parvin, 2003; Lima et al., 2017a, 2017b). However, scaling to high output powers requires the active volume to be increased without detriment to another factors such as pulse repetition frequency and specific output energy, which determined the average output powers of laser. Tube bore and tube length are intimately related via detailed kinetic properties of lasers. These factors are themselves tied to device dimensions through consideration of impedance matching and thermal management. Although the specific average output power falls as the tube bore is increased, the tube length can be increased simultaneously to optimize excitation and electrical conditions and the efficiency of laser generation generally increases (Vuchkov, Petrash, & Sabotinov, 1982). The principle limitations to increasing average output power by increasing tube bore are: the plasma skin effect and overheating of the medium on the tube axis. On the other hand, the maximum length of tube lasers is dictated by the duration of the gain period. It is desirable to have four or more resonator roundtrips during gain in order to reduce the beam divergence. The finite time for propagation of the applied field along the discharge tube will affect oscillators (Lima et al., 2017b).

In this work, some home-built halide lasers have been designed with different bores and different lengths. Copper bromide and copper chloride have been used as active medium, individually, to measuring the output power of any laser. It is found that, an optimum of length-to-bore ratio corresponded to maximum output power, is obtained for a given laser. That is, for any tube bore, there is an optimum tube length, which maximum average output power of laser can be extracted. So, we find that there is a relationship between maximum average output power of halide lasers and their tube geometrical factors, which differ from than that of CVLs.

EXPERIMENTAL SETUP

The standard discharge tubes and corresponding driven circuit were used in this experiment (Dehghani et al., 2011). A storage capacitor with different value, depends on tube's length, was discharged via a TGI1-1000/25 thyratron and the tube. A correspond peaking capacitor was also used. Some tubes were designed with different bores of 1, 2, 3, 4 and 5cm. For each bore, different related lengths of 20-160cm were employed. The discharge was contained within a quartz tube and hollow cylindrical water-cooled copper electrodes were used. One or more heated side-arm reservoir of high purity CuBr (or CuCl) powder, which were located through the tube length, depends on tube length, were used to seed the discharge zone with CuBr and CuCl, individually. The temperature of discharge channel was held at about 430 and 510 °C for CuCl and CuBr lasers, respectively. The laser cavity was formed by a flat dielectric coated high reflector and uncoated quartz flat act as an output coupler. Helium was employed as the buffer gas with optimum pressure of about 20torr, which was kept constant at any laser tube. The pulse repetition frequency was selected by a value in the range of 17-24 kHz, depends on tube's bore. The electrical input power was selected by a value in the range of 1.2-1.8 kW, depends on tube's length. The output power of lasers was measured by a Molectrom™ PM500D power meter.

RESULTS AND DISCUSSION

The behavior of output powers of CuBr and CuCl lasers versus tube length, with different bores are shown in Figs. 1 and 2, respectively. As can be seen, the behaviors of both kind of lasers are nearly the same by a little different in output powers. For each tube bore, the output power is increased by increasing of tube length, at first, and after reaching to a related maximum value, the output power is decreased. The initial increasing of output power by increasing tube length, due to increasing of active medium volume is known. But, for any tube bore, there is an optimum length, which gives maximum output power. The reduction of output power at larger tube lengths is related to deviation of beam from tube axis, which causes to absorbing of beam by wall, and reduction of feedback. From the Fig.s 1 and 2, we can obtain the relation between length (l) and bore (d) which gives maximum output power as follow,

$$\left(\frac{l}{d}\right)_{opt} \sim 30 \quad (1)$$

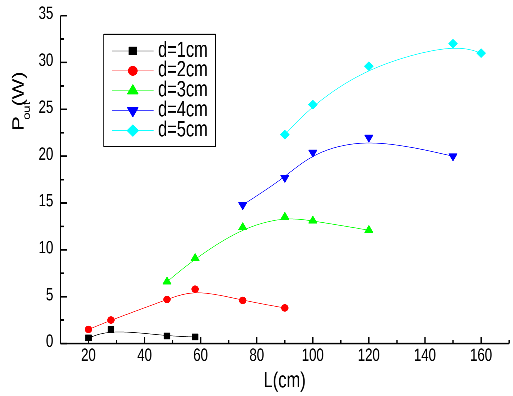

Fig.1. The output power versus length of CuBr lasers with different bores.

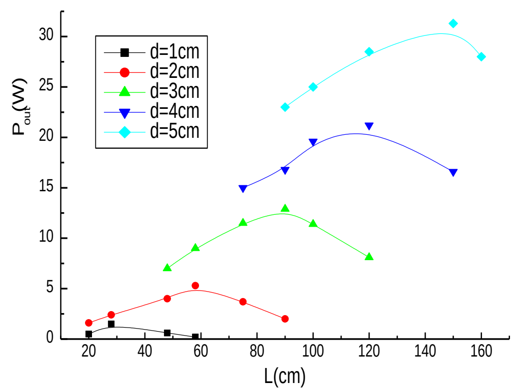

Fig.2. The output power versus length of CuCl lasers with different bores.

In other words, when the length of tube is chosen about 30 times its bore, the laser output power will reached to its highest value. This result is nearly in accordance with other works; for example, for CuBr and CuCl lasers, the (l/d) are about 25 (Vuchkov et al., 1982), 40 (Nerheim, 1978), 28 (Kazaryan, 1980), 20 (D. N. Astadjov, Dimitrov, Little, Sabotinov, & Vuchkov, 1994), 30 (D. Astadjov et al., 1997; Tiwari et al., 2014) 33 (D. N. Astadjov et al., 1997), 34 (D. Astadjov, Petrash, Sabotinov, & Vuchkov, 1984), 33 (S Behrouzinia, Namdar, Zand, Barry, & Hojabri, 2006), 32.5

(Marazov & Manev, 1990), 25 (D. Astadjov, Isaev, AA, Petrash, GG, & Ponomarev,, 1992), 32 (Isaev, 1997), 40 (Evtushenko, Petrash, Sukhanov, & Fedorov, 1999), 25 (Trigub, Shiyanov, & Evtushenko, 2013) and 26 (Dehghani et al., 2011) for CuI laser. On the other hand, we can deduced the relationship between geometrical factors and maximum average output power as follow:

$$P_{ave}^{max} \sim \frac{l\,d}{200} \quad (2)$$

Which P_{ave}^{max} , d and l are in watts, millimeters and centimeters, respectively. Meanwhile, this relation is $P_{ave}^{max} = l\,d/100$ for CVLs by taking the specific output power energy at maximum output power of 4mJcm^{-3} for CVLs ranging in tube bore from 10 to 60 mm (Little, 1999). From relations of (1) and (2), it is find that:

$$P_{ave}^{max} \sim 1.5\,d^2 \quad (3)$$

which P_{ave}^{max} is in watts and d is in centimeters. The latter straightforward relation is applicable formula for designing of halid lasers tubes.

CONCLUSION

The relationship between tube bore and its length, as geometrical factors of halide lasers have been obtained at optimum condition. The maximum average output power of halide lasers are half than that of CVLs versus geometrical factors. The straightforward relation has been obtained for designing of halide lasers tubes, so that, 1.5 times the diameter squared of tube halide laser gives maximum output power.

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