Investigation on Characteristics of 6328Å He=Ne Gas Laser

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I. Introduction

The properties of He—Ne gas laser has been investigated by many workers in this field. Yet due to the complicated dependence of characteristics especially of output power on tube parameters, no simple theory exists which could predict the detail of it. Hence more experimental investigations are required in order to reveal the output power characteristics of He—Ne gas laser.

The purpose of this investigation is to observe the output power characteristics of He—Ne gas laser at 6328Å wavelength. the result would help to obtain the optimum power output for a given tube as well as optimum operation condition. The dependence of output power on excitation power is investigated first. This yields a different result from previous observation[1] for a different laser tube. The variation of output power as well as radiation mode against the iris diameter is obtained by insertion of iris into resonator cavity. Besides, some investigation of polarization of laser beam by using polarizer variations of output power by applying different mode pattern are also made Finally the fluctuation of output power due to thermal effect is also presented.

II. Experimental Results and Discussions

1. Excitation and Output Power

The relation between the excitation and output power of 6328Å He—Ne gas laser was reported in a previous paper[1] by T. S. Wen and S. C. Wang. In that paper, saturation effect of output power versus excitation current was observed. In our present paper, this relation is further investigated using a different laser tube. The experimental result is plotted in Fig. 1. For comparison, the values reported in the previous paper[1] is plotted in Fig. 2.

It is obvious that saturation effect is not obtained for the present laser tube used. Instead of saturation of output power at increasing excitation, there exists an output power maximum at moderate excitation. At still high excitation output power tends to decrease and reaches a cutoff. As will be shown and discussed ina later section, this tendency is independent of tube temperature.

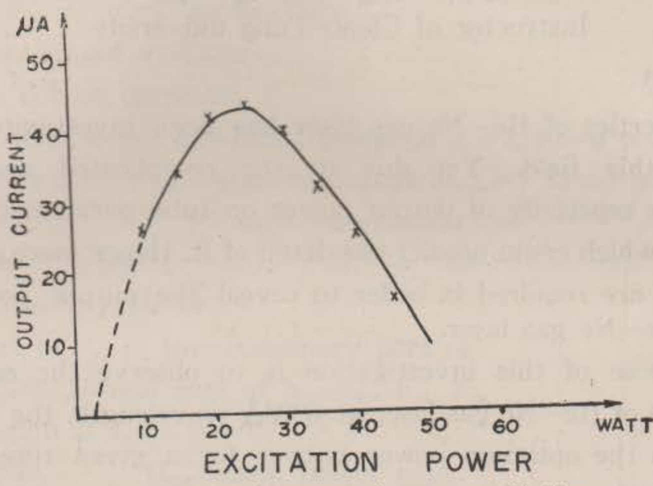


FIG. 1 output current vs excitation power for laser tube gl#7

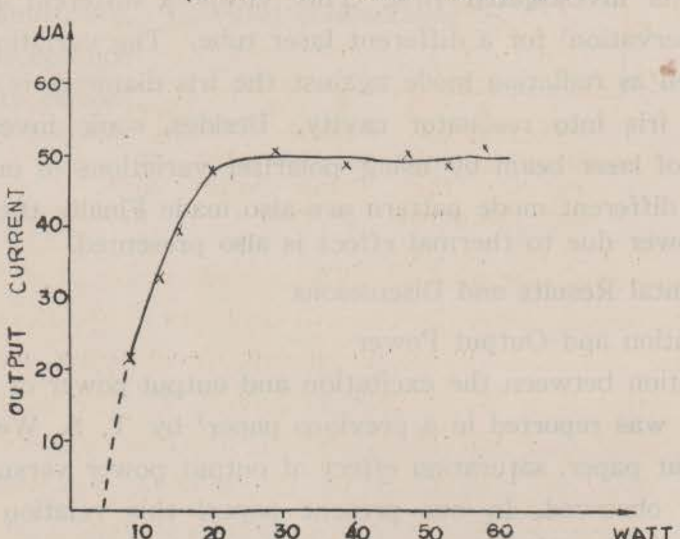


FIG. 2 output current vs excitation power for gl-#3 in reference 1

2. Diameter of iris and out put power

It is known that the amount of power obtainable in the TEM_{mn} mode of a gas laser should depend on the volume of the mode. Thus insertion of an iris with variable diameter into the laser cavity will change the output power. The experimental setup is shown in Fig. 3, and experimental results are plotted in Fig. 4.

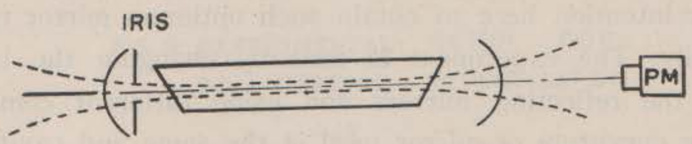


FIG. 3 EXPERIMENTAL SETUP FOR INTERPOSING IRIS

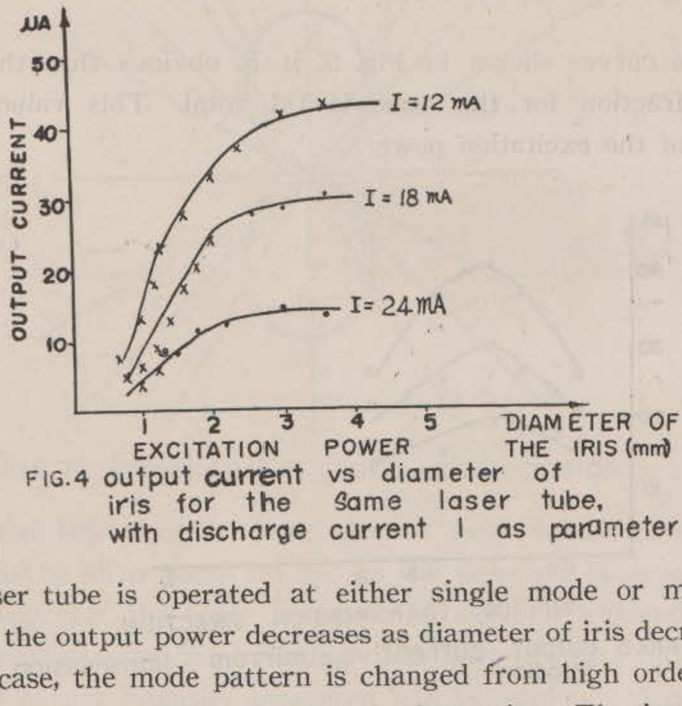


FIG. 4 output current vs diameter of iris for the same laser tube, with discharge current I as parameter

The laser tube is operated at either single mode or multimode. In either case, the output power decreases as diameter of iris decreases. In the multimode case, the mode pattern is changed from high order transverse mode to low order mode as diameter is decreasing. The increase of diffraction loss due to insertion of iris and the decrease of mode volume of the oscillating mode are considered as the main reasons responsible for decreasing in output power. The suppression of high order transverse multimode oscillation by insertion of iris suggests a way for obtaining single mode oscillation which is required in wideband communication.

3 Mirror transmission and output power

A theoretical analysis of optimum transmission fraction for 1.15 μ He—Ne gas laser was made by w. w. Rigrod[3]. The result indicated the dependence of optimum transmission fraction on saturation parameter, or the characteristics of active medium. For different kind of laser tube with different parameters there will be different optimum transmission fractions.

It is our intention here to obtain such optimum mirror transmission experimentally. The experiment is done by changing the transmission fraction of the reflecting mirrors and using different combination of mirrors. The curvature of mirror used is the same and cavity length is kept constant, such that the output power would not be affected by configuration of resonator cavity. The experimental results are plotted in Fig. 5.

From the curves shown in Fig. 5, it is obvious that the optimum tranmission fraction for this tube is 1% total. This value is almost independent of the excitation power.

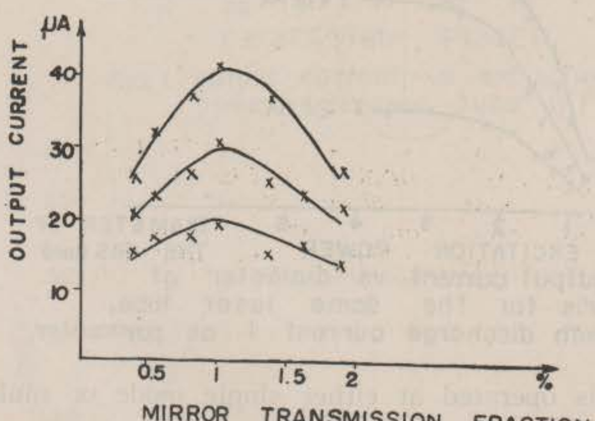


FIG. 5 output current vs mirrors transmission fraction

4. polarization of laser beam

The laser beam radiated throughthe Brewster window is considered to be linearly polorized. In order to investigate the polarization of output radiation, an attempt is made to put a rotatable polarlzer film in path of radiation beam. A scematical arrangement of experiment is shown in Fig. 6. The laser beam passes through the polarizer perpendicularly and reaches the photomultiplier detector. By rotating the the polarizer, the output intensity variation is observed. Experimental results are plotted in Fig. 7

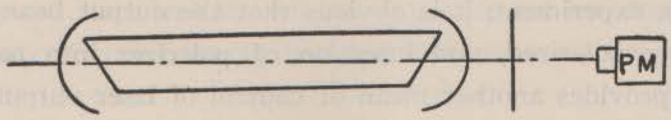


FIG. 6 EXPERIMENTAL SETUP FOR POLARIZATION INVESTIGATION

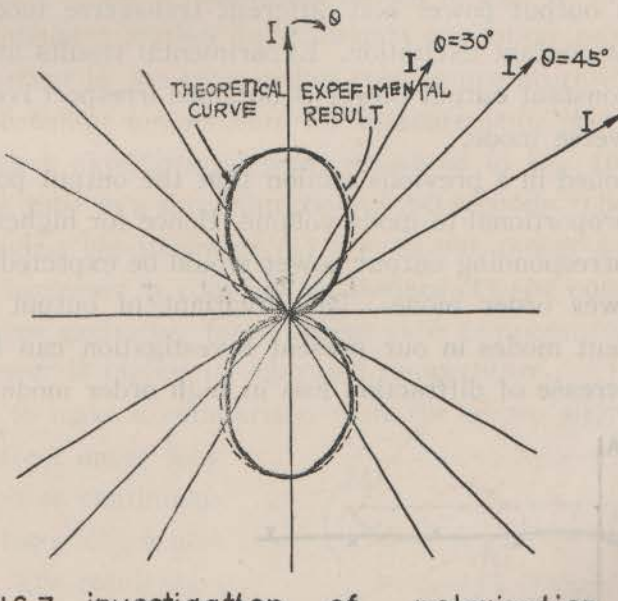


FIG.7 investigation of polarization

Since the laser beam whose electric field coincides with that of polarizer will be all transmitted and as the polarizer is gradually rotated in such a way that the angle between the electric field and direction of polarization of polarizer is increasing, then part of beam intensity will be cut out and output intensity measured will be gradually decreased.

Since the beam intensity is proportional to square of electric field, and if the angle between the electric field and direction of polarization of polarizer is said to be θ, then the light intensity passing through the polarizer will be

$$1 \propto E^2_{max}\cos^2\theta = E^2_{max}\,\frac{1+\cos 2\theta}{2}$$

a plot of this relation in polar coordinate is also shown in Fig. 7 in the solid curve. this curve fits well with the experimental results obtained.

From this experiment. it is obvious that the output beam of laser is almost linearly polarized, and insertion of polarizer into path of beam transmission provides another mean of control of laser output power.

5. Mode Patterns and Output power

The mode patterns of laser beam can be varied by micro-adjustment of mirror mount as reported in a previous paper[1]. In the present work the relation between output power and different transverse mode oscillation is investigated at contant excitation. Experimental results are plotted in Fig. 8. A fairly constant output power is obtained irrespect ive of different oscillation transverse mode.

It has mentioned in a previous section that the output power of laser beam is nearly proportional to mode volume. Hence for higher order mode oscillation the corresponding output power would be expected to be larger than that of lower order mode. The invariant of output power with respect to different modes in our present investigation can be explained as due to the increase of diffraction loss in high order mode oscillation.

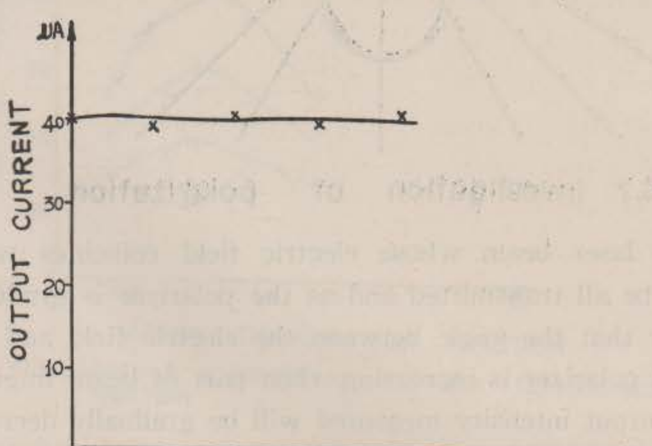


FIG. 8 output current for different TEM_{mo} modes

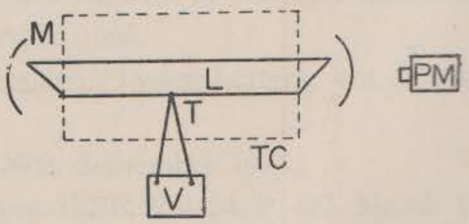
6. Thermal effect in Output power

When the laser tube is operated continuously, the fluctuation in output power is always observed. Besides, the relation between excitation power and output power also depends on tube temperature. This point of the report presents some results of the experimental investigation on this effect and more detail investigation and discussion will be presented in a next report.

A schematical experimental setup is shown in Fig. 9. Laser tube temperature is measured by thermocouple and tube temperature is controlled by an enclosed control set into which the cooled air (oxygen) is pumped. Experimental results are shown in Fig. 10, and Fig. 11.

At continuous operation under certain excitation power, the flow of excitation current in the tube makes tube temperature increase. In order to maintain constant temperature for measurement, short time operation is adopted. Each experimental point measured in Fig. 10 is obtained by operating the tube in a short duration of 2-3 seconds. The result obtained has the following significances: (1) the output power increases as tube temperature increases at constant excitation; (2) the output power has a cutoff at higher excitation for different tube temperature and the cutoff excitation power is higher for elevated temperature.

In order to make a comparison with the above short time observed result, the effect under long time operation or continuous operation of laser tube is also investigated. The result shown in Fig. 11 is obtained by cooling the laser tube near to liquid oxygen temperature and then operate the tube continuously under constant excitation. The output power is measured continuously as the tube temperature is increasing due to its own current flowing. The monotonical increase in output power with respect to temperature is



L: LASER TUBE M: MIRRORS

T: THERMAL COUPLE V: VOLTMETER

TC: TEMPERATURE CONTROL SET

PM: PHOTOMULTIPLIER

FIG. 9 EXPERIMENTAL SETUP FOR MEASUREMENT OF THERMAL EFFECT.

obvious. That the increase of output power with increasing temperature is independent of operation condition.

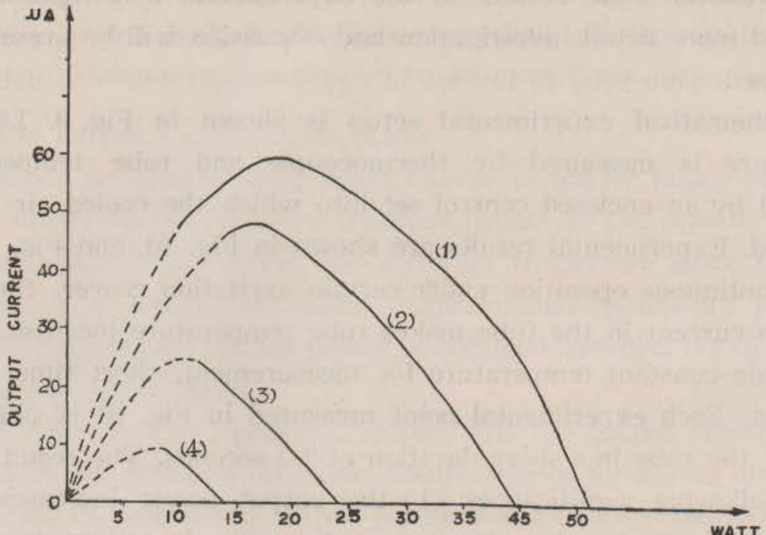


FIG.10 output current vs excitation power curve with temperature as parameter
(1) T = 300°K (2) T = 273°K (3) T = 217°K
(4) T = 185°K

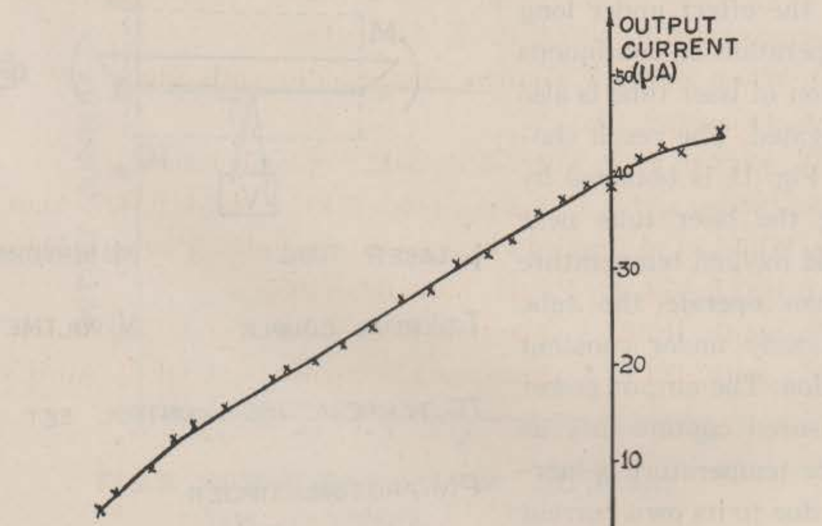


FIG.11 output current vs long time variation of temperature

III. Conclutions

From the above experimental investigation and results obtained, we may say that for a given laser tube the output power can be optimized by its excitation power, hence provided with highest power output. The output power can also be optimized by mirror transmission fraction. The effect variation of tube temperature on output power suggests that operating the laser tube at certain elevated temperature is preferable. while for minimizing the fluctuation in output power for continuous operation care must be taken in order to maintain constant tube temperature. In our case forced air cooling by electric fan is used throughout the experiment.

Acknowledgements

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