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RESEARCH PAPER

Out-put Characteristics of Low Power He-Ne Laser Efficiency Determination

Gullala. Y. Baker
Department of Physics, College of Education, Salahaddin University- Erbil, Kurdistan Region, Iraq

A B S T R A C T:
It is known that any laser has a pumping source, an amplifying medium and a resonator that oscillates the active mode representing the out-put wavelength of the laser. The suitable value for this ratio is 7:1 He/Ne in volume. These were to prepare under an ideal mixture of these gases as treated before by many experiment lists. The aim of this study to specify is to the basic portions of low power He-Ne gas lasers available in laboratories, and to test them in order to look for a probable factor of the efficiency as the whole. All calculations were performed, using calculators. The results were unique for all of them that the laser aperture also plays an important role in this criteria. The best fitting ratio between the radius of laser aperture and that of laser beam was determined and connected to the other parts of the efficiency, also the ratio of(ρ/ω) was fixed at 1.55.

KEY WORDS: Laser Efficiency; Out-put power; Laser aperture, Minimum pumping power, Laser Amplification.
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1.INTRODUCTION :

When a gas is discharged in a low temperature plasma range, ionization is followed by a few consequent processes such as scattering, excitation, pair production and radiation(Hasted, 1976). Gas discharge in laser resonator has different functions since, the discharge followed by beam formation in Gaussian shape then amplification and saturation occurs in the medium(Yariv and Gordon, 1963). When a beam oscillates inside a laser resonator, the amplification quality depends in many factors including; end-mirror sizes, the plasma density and input electrical power (Born and Wolf, 1964). The overall process determines the laser efficiency which is different from other efficiencies in electrical and mechanical system.

* **Corresponding Author:**
Gullala. Y. Baker
E-mail: glalabakr@gmail.com
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This difference arises from that the laser resonator is an amplifying design, which concentrates the beam towards a tiny aperture of less than a millimeter in diameter(Hecht, 2018). In this study, few laser tubes were tested having out-put powers{1,2,3,5,10,15,20,30and35}m watts respectively. In all of these the basic parameters to be known are (Yariv, 1967)[5].

1-The electrical in put power [$P_{in}=V_{in}I_{in}$] which is the characteristic of the gases{He and Ne}with in the plasma tube V_{in} is entering Voltage and I_{in} is the input dc current.

2-The resonator geometry {length, mirror sizes and reflectivity's…. etc.

3-the plasma tube specifications including [cathode and anode} distance, the gas ratio He/Ne, the total pressure and discharge saturation times.

4- Physical and chemical properties of the laser coatings and their structure.

5-Finally, the power types are to be identified in order to specify and enhance their characteristics.

2.Theory:

From the parameters mentioned in the introduction one can get the formulas for basic parts of the power which ends of the outside plane of the output mirror, mentioned as the transmitted or useful out-put power(Abdul-Rahim and Mawlud, 2013).

In this case and according to their order of performance, these were the following:

1- The input electrical power coming from the step-up transformer as V_{in} and I_{in} respectively. So:

$P_{in} = V_{in} I_{in}$ in watts … (1)

2-Minimum pumping power (MPP) which is the necessary power needed to assure the desired process of population inversion, it is the function of the oscillating photon energy, the volume of the capillary tube and the lifetime of the upper level T_u in seconds(K. Evans and Sommerfield, 2015). This is

$MPP = h\nu \Delta N V/\tau_u$ …(2)

Here ΔN is the optimum population inversion density in m^{-3}, v is the volume of capillary tube in m^3 and τ_u is the mean life time of upper laser state.

The maximum output power stored in the resonator known as P_{sat}, which is:

$P_{sat.} = I_{sat.} A$ …(3)

Here A is the the cross-sectional area of the laser beam, $I_{sat.}$ is the saturated intensity of the laser beam and it is the characteristic of photon energy(hν), the σ_{st} is the stimulated emission cross section, and the saturated life time of the process.τ_{sat} :

$\therefore I_{sat} = h\nu / \sigma_{st}. \tau_{sat}$ …(4)

In unit of watt/m^2 .

σ_{st}. is also the function of active medium characteristics.

4- the central power at the center of the resonator P_0, which is the (Urquhart, 2020).

$P_0 = Lg_0/2[1-(a_0/Lg_0)^{1/2}]^2 I_{sat} A$ … (5)

Where Lis the resonator length, g_0 is the gain coefficient, a_0 is the loss factor is equal to 0.005, and in equ.5 the whole bracket $[1-(a_0/Lg_0)^{1/2}]$ represents the aperture efficiency.

Now, on the behalf of these information's, the individual parts of the laser efficiency could be defined as(Morace et al., 2019):

a- $\eta_{pump} = \frac{MPP}{Pin}$ …(6)

b- $\eta_{res} = \frac{P0}{Psat}$ …(7)

c- $\eta_{ap} = 1-e^{-2\rho 2/\omega 2}$ … (8)

Where η_{pump} is the pumping efficiency, η_{res} is the resonator efficiency η_{ap} is the aperture efficiency. In equ.8, ρ is the radius of laser aperture and ω is the radius of the beam.

2.Results and discussion:

Throughout the whole work, parameters are the Own of the laser tubes such as their out-put their length, density and geometric parameters, and the He:Ne ratio was fixed as7:1 involves. From these the calculated portions of the efficiency were drown individually as in Figures1, and2, respectively, the results show that their values are different, according to different input parameters, the common values of these were (Bartal et al., 2012).

1-The small signal gain coefficient, go=0.1m^{-1}

2-The scattering and absorption coefficient, a_0=0.005

3-Stimulated emission cross-section,$\sigma_{st}=3*10^{-17}$ m^2

4-life time of upper laser level,$\tau_u=3*10^{-8}$ sec.

5-Population inversion density ,$\Delta N=5*10^{15}$ m^{-3} .

From these, one can determine the fixed ratio ρ /ω, which was optimum for all laser tubes as (1.5). Also, the idea of the laser aperture to be part of the process was clear in calculating the total power efficiencies as (Cockbill, 2017):

$M_{ap=} P_{out} /P_o$, here P_{out} and P_o are the out put power and the central power stored in the resonator. Where P_{out} ,

$P_{out} = P_{in}[1-e^{-2\rho 2/}$ ω $^2]$ ………(9)

The results revealed that the effective part of these was the resonator efficiency.

The results were very close to standard evaluation of total laser efficiency, since the optimum value of common produced He-Ne laser exceeds (10^{-4}) slightly.

Figure١ represents the graph of the resonator efficiency as the function of Pout for the laser. Figure2 is the plot of (ρ/ ω) as the function Transitions of out put mirror $[1-e^{-2r2/}$ ω $^2]$ r is the variable value of ρ. Finally, Figure٣ is the variation of Resonator Efficiency as the

function of total power stored in the resonator
.
Figure ٤ is the variation of power output against the power stored of the laser.

Table 1: Variation of the efficiency resonator as a function of output power.

P_{out}	$\eta_{res.}$	P_{out}	$\eta_{res.}$
1	4094116.6330839800	16	8140995.4877139800
2	4363160.8667709000	17	8411403.5125626300
3	4632349.7439486100	18	8681866.3268220600
4	4901671.0285245500	19	8952381.4203046600
5	5171114.1180711600	20	9222946.4688368900
6	5440669.7538544300	21	9493559.3155148900
7	5710329.7938613800	22	9764217.9543208100
8	5980087.0328641500	23	10034920.5157464000
9	6249935.0581287300	24	10305665.2541313000
10	6519868.1325000000	25	10576450.5364722000
11	6789881.0987705900	26	10847274.8325000000
12	7059969.3007809600	27	11118136.7058526000
13	7330128.5178064100	28	11389034.8061998000
14	7600354.9095944200	29	11659967.8621976000
15	7870644.9700126400	30	11930934.6751675000

Table 2: Variation of aperture to beam radius ratio against the transitions of output mirror.

$1-e^{-2(r/w)2}$	0.95606	0.96414	0.97092	0.97902	0.98508	0.99074	0.9927	0.9950	0.9956
ρ/ω	1.25	1.29	1.33	1.39	1.45	1.53	1.57	1.63	1.65

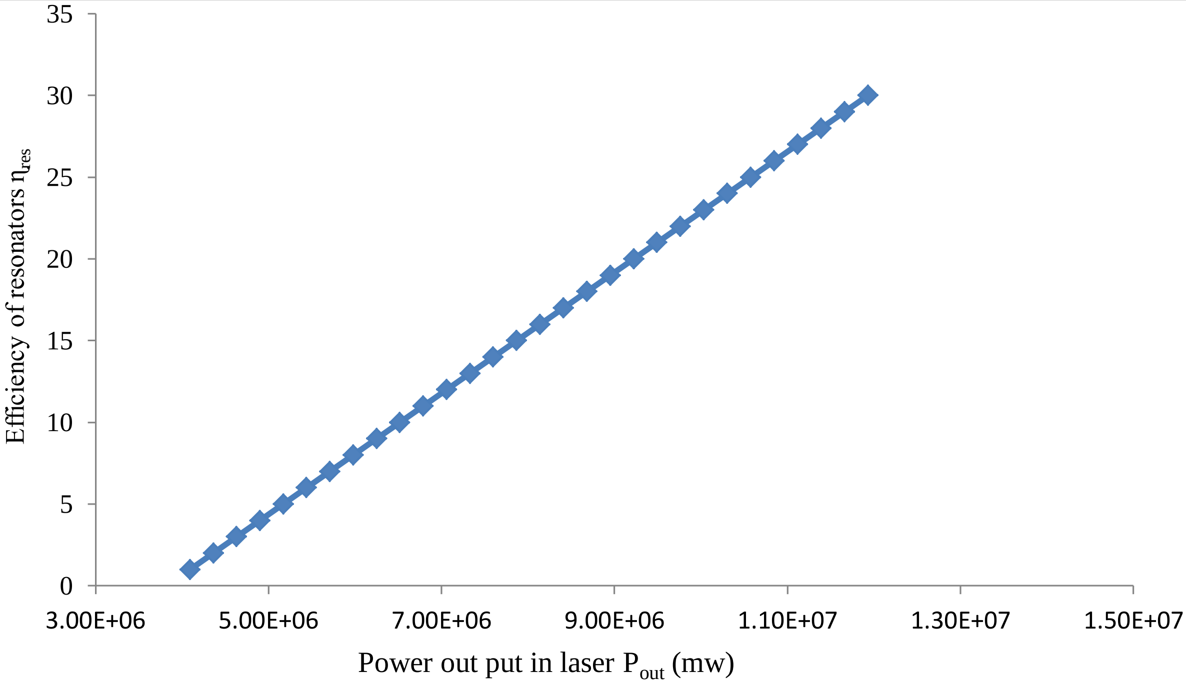
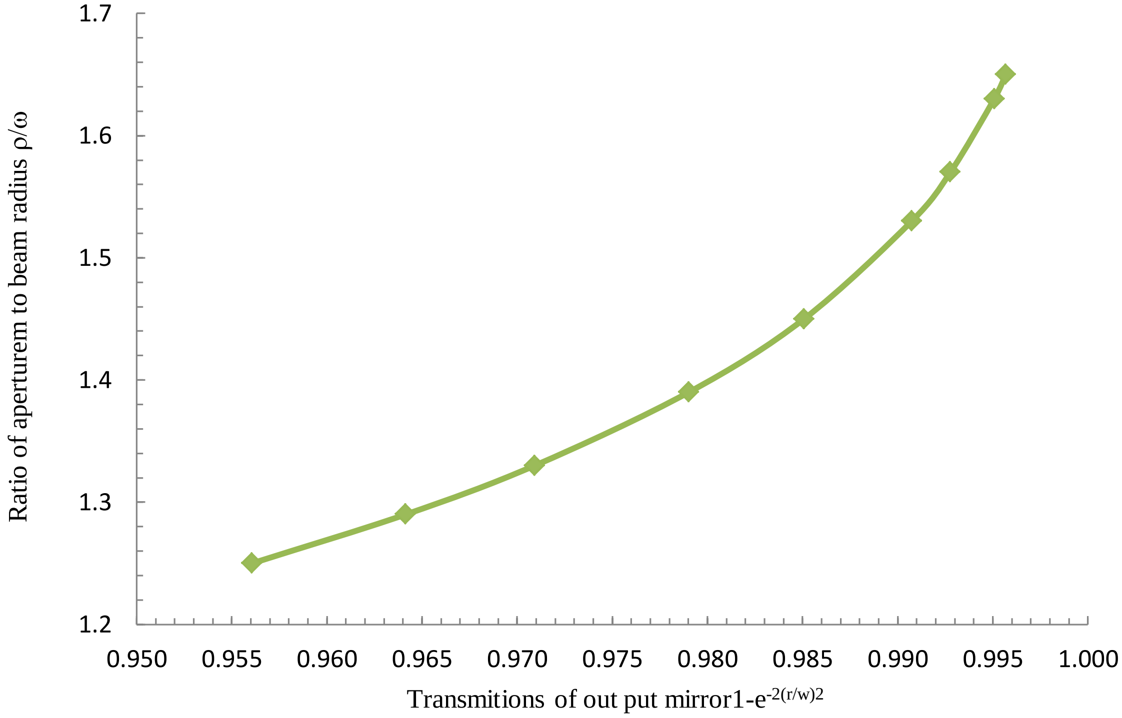


Fig. (1):Variation of the efficincy resonator $\eta_{res.}$ as a Function of Pout put in laser.



Fig(2):Varation of the aperture to beam radius ratio against the transmitions of out put mirror M2$\{1-e^{-2(r/w)2}\}$.

Table 3: Variation of resonator efficiency as a function of total power stored in resonator.

P_{stored}	4.415	6.413	6.791	15.698	20.113	54.328
$\eta*10^{-2}$	0.167	0.195	0.225	0.426	0.715	1.3883

Table 4: Variation of power output against the power stored of the laser.

P_{stored}	P_{out}	P_{stored}	P_{out}
4.0941166331	1	8.1409954877	16
4.3631608668	2	8.4114035126	17
4.6323497439	3	8.6818663268	18
4.9016710285	4	8.9523814203	19
5.1711141181	5	9.2229464688	20
5.4406697539	6	9.4935593155	21
5.7103297939	7	9.7642179543	22
5.9800870329	8	10.0349205157	23
6.2499350581	9	10.3056652541	24
6.5198681325	10	10.5764505365	25
6.7898810988	11	10.8472748325	26
7.0599693008	12	11.1181367059	27
7.3301285178	13	11.3890348062	28
7.6003549096	14	11.6599678622	29
7.8706449700	15	11.9309346752	30

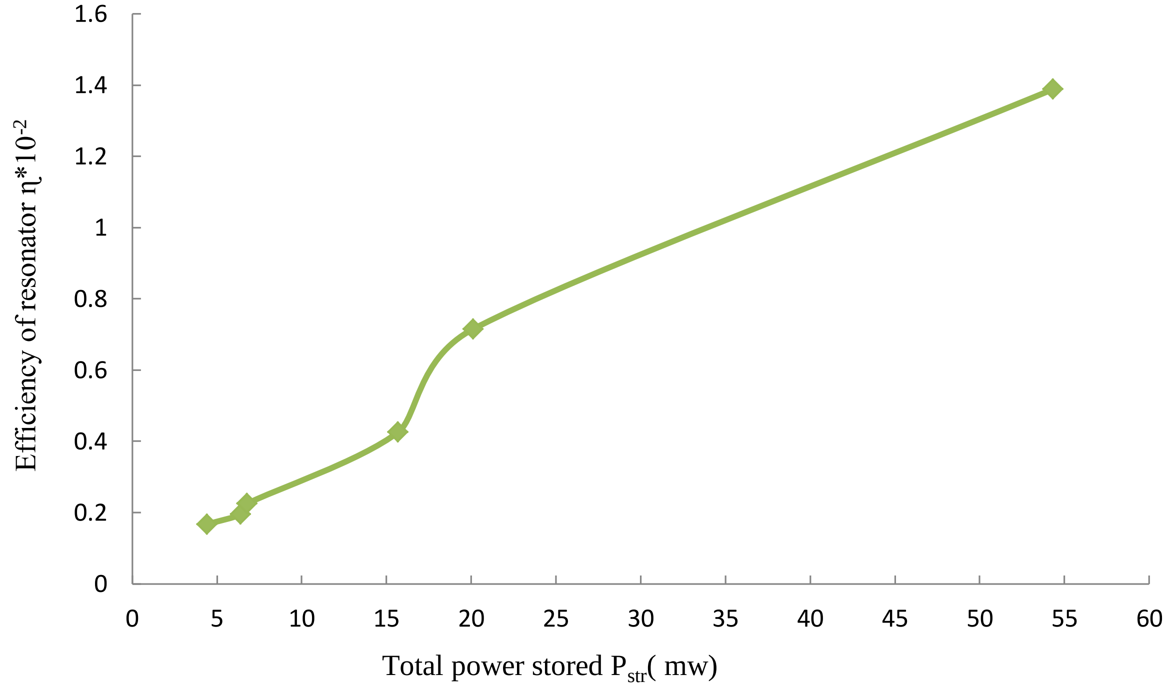


Fig.(3):Variation of Resonator Efficiency as afunction of total power stored in Resonator.

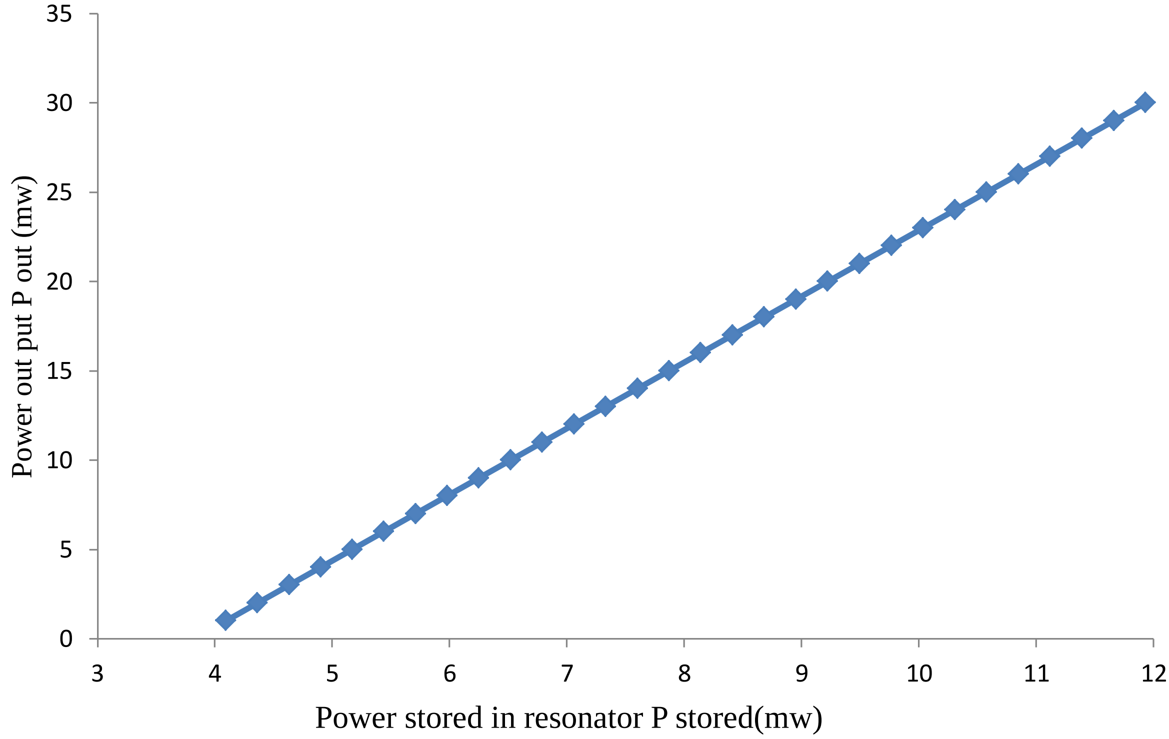


Fig.(4):Variation of Pout power against the power stored of the laser

4. Conclusion

Throughout the whole work, it was clear that estimation of the overall efficiency of any laser tube is a very complicated process, since it is a non- liner combinations of many parts. The essential parts are the laser aperture, the input power and the resonator efficiencies. From efficiencies of these one can conclude the following:

1-Both the aperture radius and the input power changes linearly with the output power. This Means they have no saturation limit for gas lasers.

2-The only part effective on the total efficiency of the gas laser is the power stored in the resonator ,since this part depends on the geometry of the resonator and the other two parts mentioned above.

3-For low-power He-Ne gas lasers, the jump in resonator efficiency between [1-10] mw, due to the very low efficiency of the input power and aperture efficiency ,almost between [10^{-5}-10^{-4}].

4-Finally, the efficiency of high power gas lasers, such as,Co_2 lasers are much higher than low power He-Ne lasers, since He-Ne lasers have very low efficiencies, unfortunately there were no any relevant references for this.

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