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OPTIMIZATION OF THE GEOMETRICAL PARAMETERS FOR THE OUTPUT MIRROR IN A HE-NE LASER

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ABSTRACT

The aim of this study is to produce a model via iterative description of the beam distribution to connect the output power of a He-Ne, continuous and low power laser in terms of its beam radius by operating it as regular pattern of repeated wave front with in the space between the mirrors. Because of the spherical shapes of laser resonators have complete Gaussian shapes. Hence the beam radius changes according to its position and along the principle axis of the cavity. We used a LASCAD simulation program as an analyzer for our data; the results didn't change that much with those of original Gaussian beam model.

KEYWORD: *He-Ne laser, Gaussian beam, Iteration, beam quality.*

I. INTRODUCTION

The laser resonator has mostly a pair of identical concave mirrors with super high reflective input one (typically 100%, and an out coupler of typically 95-99% reflectance. The Gaussian nature of the beam distributions makes the beam radius to increase as the distance increases from the resonator center [Siegman A., 2001]. As the results of this distribution, the parameters in question, necessary in producing the emerging laser beam are:

1- Engineering dimensions (g-parameter)of the resonator are:

a- The surface area of mirrors (A).

b- The radius of curvature for spherical symmetric resonator (R).

c- The physical distance between mirror centers of curvature (L).

2- The beam characteristics represented by their power behavior with the beam center $1/e^2$, which are the radius and intensity distributed.

3- The total created power by stimulated emission and the output power emerging from the laser aperture [Gahtak A., 1984].

Figure (1) represents a typical low power gas laser resonator with specifications described in (1), namely (A), (R) and (r) for (a), (b) and (c) respectively.

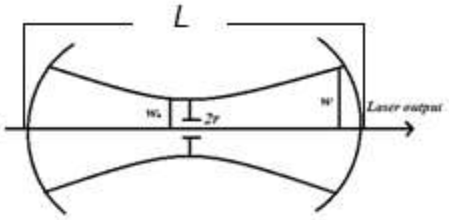

Fig. (1): Represents a typical low power gas laser resonator

Here r is the beam distance from z laterally, w_o is the min waist spot size, and w is the beam radius at the surface of the output mirror.

II. THE LASER OUTPUT POWER PROFILE

In classical Electromagnetic theory, the Transverse E-field can be written as [Lee P., 2006]:

$$E(r) = E_\circ e^{-r^2/w} \dots\dots\dots\dots\dots (1)$$

Here $E_\circ$ in the field strength at the center, (w) is the beam waist at (z) distance and, (r) in lateral distance from the beam center, where $r^2 = x^2 + y^2$, The average intensity of the beam is related to E [Jaegwon Yoo, B. C. Lee and Y. J. Rhee, 2004]:

$$I = \frac{\epsilon_\circ c E^2}{2} \dots\dots\dots\dots\dots. (2)$$

Converting this into central field strength,

$$I_\circ = \frac{\epsilon_\circ c E_\circ^2}{2} \dots\dots\dots\dots\dots.. (3)$$

Combining these equations:

$$I = \frac{I_\circ}{e^2} \dots\dots\dots\dots\dots. (4)$$

and

$$I(r) = I_\circ e^{-2r^2/w^2} \dots\dots\dots\dots..(5)$$

Where $I_\circ \propto E_\circ^2$

Since the power $P=I*area$, so the radial power contained within arbitrary radius (r) or the beam by integrating equation (5) over (r) and (2π)as:

$$P(r) = \int_0^r \int_0^{2\pi} I_\circ e^{-2r^2/w^2}\, d\theta r dr \dots\dots\dots\dots (6)$$

Where $da = r dr d\theta$is an infinitesimal area element plane polar coordinate, performing integral of (6):

$$P(r) = \frac{I_\circ \pi w^2}{2}\left[1 - e^{-2r^2/w^2}\right] \ldots\ldots\ldots\ldots (7)$$

At $r \to \infty$ extra far field propagation, then:

$$P(\infty) = I_\circ \frac{\pi w^2}{2} \ldots\ldots\ldots\ldots\ldots (8)$$

Combining eq. (7) and eq. (8) we get:

$$P(r) = P(\infty)\left[1 - e^{-2r^2/w^2}\right] \ldots\ldots\ldots (9)$$

At r=w

$$P(r) = P(\infty)\left[1 - \frac{1}{e^2}\right] = 0.865\, P(\infty) \ldots . (10)$$

This equation shows that only 0.135 of the total power stored in the cavity will be lost at result of running away from$(r = 0) \to (r = w)$. Since eq. (10) is obeyed along the whole cavity length, this means that the power created inside the resonant cavity is independent on the beam waist (w) at $\frac{1}{e^2}$ points. These points could be selected along the z-axis according to what is called Newton-Raphsor iterative criterion [Chattopadhyay D., 2006]. This iteration is selected such that the step change in the value $(1 - \frac{1}{e^{-\frac{2r^2}{w^2}}})$ could be very small in eq.(9). For example if (w=0.1m). The real meaning of cavity iteration is to minimize the effect of increasing in (r) away from the axis center so that it could be divided in to a number of equal periodical distance such that the difference between two consequent values of (r) does not exceed a μm or so.

In practice, the numeration of interval values in (r) complicates the applicability of eq. (7), but as we have said above the change interval value of (r) in microns is the periodicity in the value of $(w - w_\circ)$ as (100) 0r (120) microns optimum [Jes H., 2009].

III. RESULTS AND DISCUSSION

Fig. (2) represents a plot of the variation in the $(\frac{1}{e^2})$ points, which is the spot size $w(z)$ as a function of the iteration repetition rate is equal values of (r) at different axial distance (z) from the center of the cavity where z=0 and $w(z)$=$w_\circ$. Fig. (3) represents the variation in beam spot size in (μm) at $(\frac{1}{e})$ points, amplitude version of the function $\left[E(r) = E_\circ e^{-\frac{r^2}{w^2}}\right]$ where $E_\circ$ is the central field amplitude at r=o and (w) is the spot size. From fig. (2) and fig. (3), it is clear that the iteration of the amplitude variation is less effective other than the power and intensity variations, because of the slightly change in the value of $(\frac{1}{e})$ rather than in $(\frac{1}{e^2})$ changes as occur in power and intensity [Jaegwon Yoo, B. C. Lee and Y. J. Rhee, 2004].

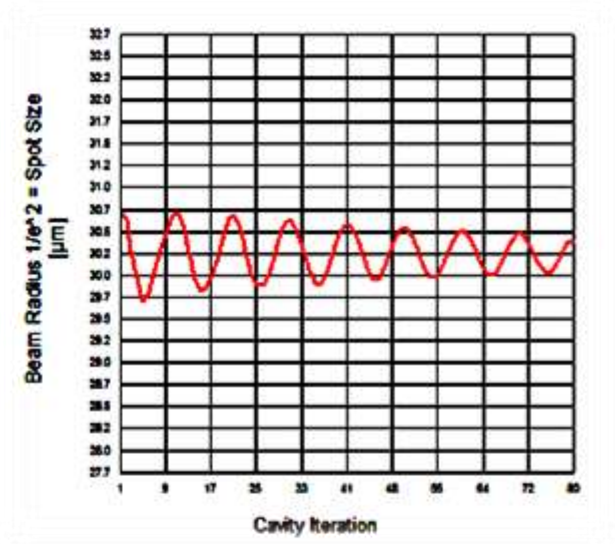

Fig. (2): Variation of the spot size versus cavity iteration.

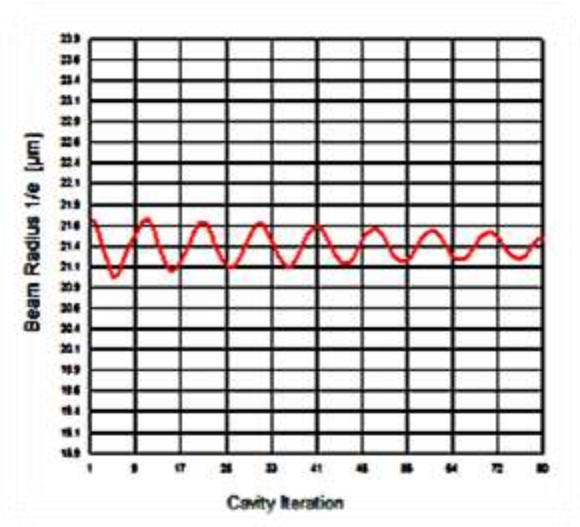

Fig. (3): Variation of the beam radius versus cavity iteration.

Figure (4) and (5) represents the plot of beam radius and power variation with the beam center (r=0) respectively. It is quite clear that power is decreasing with the exponential reciprocal of squared radius (r^2) and the beam radius increase exponentially with axial forward distance from the cavity center (z=0) these are compared formally with those of Lee [Lee P., 2006].

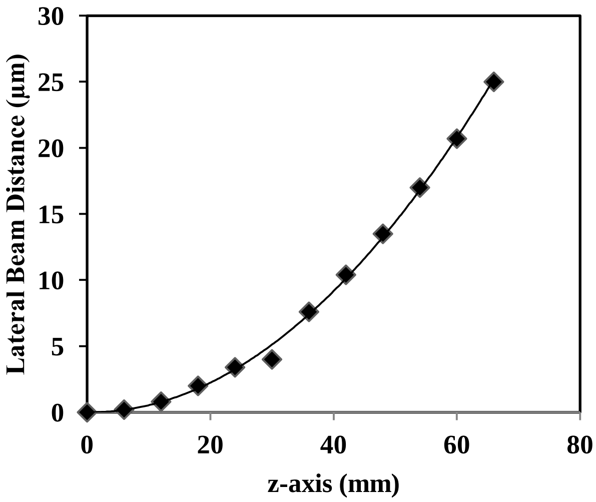

Fig. (4): Variation of lateral beam radius with distance along z-axis

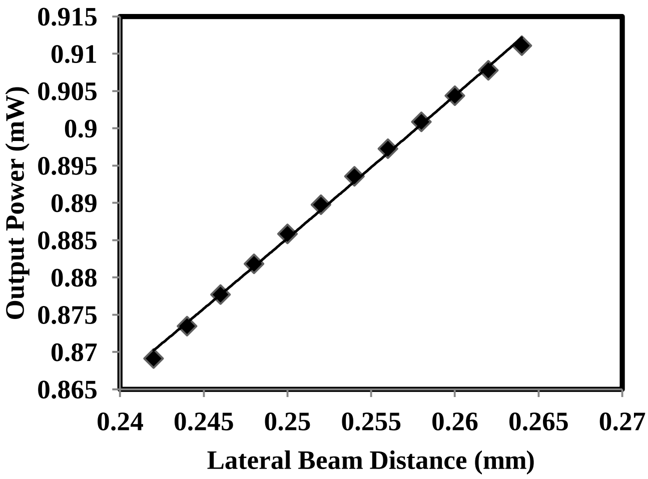

Fig. (5): Variation of lateral beam distance with output power inside the resonator.

The numerical expression for the beam quality of laser system can be written as [Cortes R. and et al., 2008]:

$$M^2 = \frac{\pi w_\circ \theta_\circ}{\lambda} \ldots\ldots\ldots\ldots\ldots (11)$$

Where $\theta_\circ$ cone half angle. The beam radius along the propagation axis (z-axis), can be written as [Jin Qian and et al., 2012]:

$$w^2(z) = w_\circ^2 \left[1 + \left(\frac{\lambda M^2}{\pi w_\circ^2}\right)^2 Z^2\right] \ldots\ldots\ldots\ldots\ldots\ldots (12)$$

The beam quality factor gives a description of how well a laser beam can be focused. The ideal Gaussian beam has an M^2 factor of 1. The M^2 factor increases all the more than the actual beam deviate from the ideal Gaussian beam. noticing that M^2 equals 1, we have a perfect Gaussian beam. Higher values for M^2 means poorer beam quality [Cortes R. and et al., 2008, Jin Qian, ant et al., 2012]. A method for measuring the M^2 factor consists of measuring the beam radius in different transverse planes around the position of the beam waist and to adjust the theoretical equation (12) with the M^2 factor as fitting parameter. Figures (6) and (7) are quite clear that the dots represent selected experimental value for axial distances with the beam center. This means that both theoretical and experimental values of p(r) coincide on each other, unless the geometrical parameters and the output power to be on request are changing depending on the type of application, which the companions suggest [Jin Qian, ant et al., 2012].

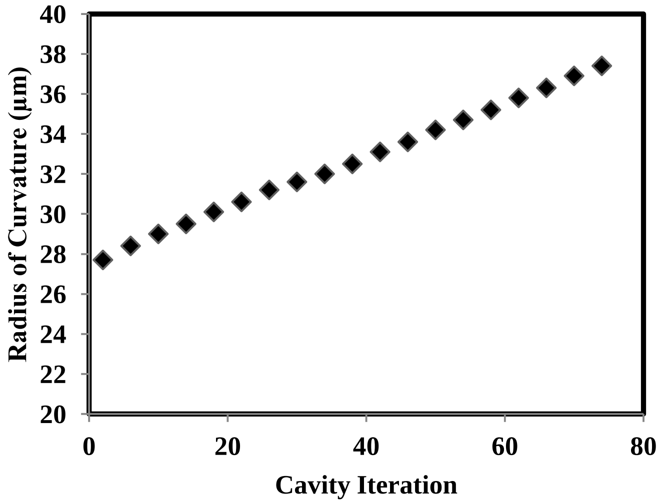

Fig. (6): Variation of radius of curvature with cavity iteration.

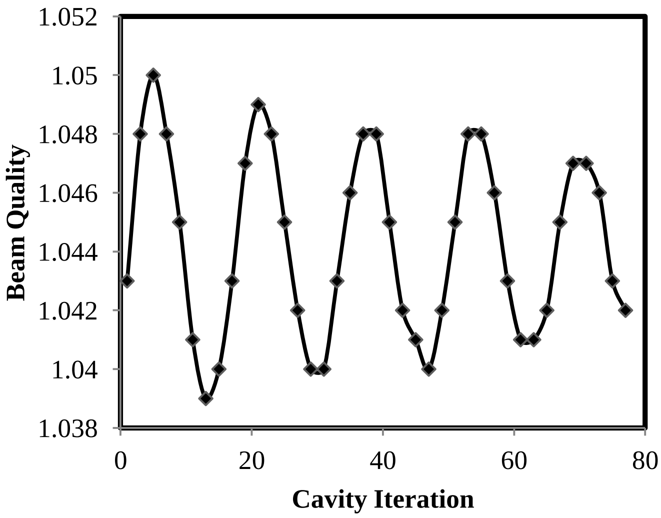

Fig. (7): variation of beam quality with cavity iteration.

IV. CONCLUSIONS

Since the laser output induced power and the beam radius depend on both distance from the beam center where (r=0), this means that each of them varies axially according to their correspondent equations (8) and (4) respectively. The power decreases exponentially squared and the beam radius increases radialy along the principle axis of the cavity. We have investigated these variations with the aid of convenient standard simulation programs LASCAD and according to the availability of the equation mentioned earlier. Thus our limit of changing the parameter lies between $(r = 0 \rightarrow r = w)$ and within the inverse $(0 \langle p \langle p_o)$, this means that the central power produced in the center of the cavity have maximum intensity $\left(I_o = \frac{p_o}{w_o^2} \right)$. And another important sequence of the work is that the beam radius has to be reiterated consequently so that the variation in its value ranges from zero to the boundary of *w/10*. This makes the calculation to take its track correctly and with infinitesimal repetition. In stable resonator as the laser resonator in use in our study, the number of round trip iterations, the number of changing in the $w(z)$ position per unit length is imaging directly the impact number of (r) variation.

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به نموونەیی کردنی بارامیتەراتی ئەندازەیی لە ئاوێنەی دەرەکی بۆ هیلیۆم-نیۆن لەیزەر

پوختە

ئامانج لەم لێکۆڵینەوەیە بریتیە لە دانانی مۆدێلێکی تایبەت بە دابەش بوونی گورزەی تیشکی لێزەر لە ناو زرنگێنەرێکی لێزەری (هیلیۆم-نیۆن)ی کەم توانا، ئەمەش پەیوەستە بە رێچکە ، توندی و پێوانە ئەندازەییەکانی زرنگێنەرەکە. لێرەدا دەبێت گورزەکە گاوسیانی خاوێن بێت و وونبوونی ووزە تیایدا نموونەیی بێت. بەرنامەی لاساییکردنەوە (LASCAD) وەك شیکەرەوەیەك بەکارهێنراوە، و ئەنجامەکان زۆر هاویەك بوو لەگەڵ بنەماکانی گورزەی گاوسی بۆ مۆدێلی سەرەکی.

تحسين المثلى للبارامترات الهندسية للمرآة الإخراج في ليزر الهليوم – نيون

الخلاصة

الهدف من هذه الدراسة هو تصميم نموذج خاص بالحزمة الليزرية في داخل مرنان ليزر (الهليوم–نيون) ذو القدرة الواطئة. و يرتبط هذا النموذج بطور، مسار و القياسات الهندسية للمرنان. و بما ان الحزمة كاوسية و نقية حسب قاعدة المرنان فأن الخسائر تكون اقل مما يمكن. تم استخدام برنامج المحاكات كمحلل للبيانات. النتائج النهائية كانت مشابهة الى حد بعيد مع النمط الكاوسي الأصلي للحزمة.