Study on diffraction losses of laser simulators*

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Abstract: The divergence provided by the semiconductor laser are all defined at the point of half power. In practical calculation, it must be transformed to another define level and the measurement divergence of LOC laser is rather great. So the transformation formulas of divergence for a Gaussian beam are modified in this paper. According to the modification, the formulas of diffraction losses of the laser simulators are derived. As the examples, the diffraction losses of three types of laser simulators are calculated.

Key words: diffraction losses　laser simulators

激光模拟器衍射损耗的研究

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摘要: 半导体激光器给出的是半功率点处的发散角, 在计算时必须进行变换, 因实测 LOC 激光器发散角较大, 本文对高斯光束发散角变换公式进行了少许修正, 导出了模拟器衍射损耗公式, 并计算了三种模拟器的衍射损耗。

关键词: 衍射损耗　激光模拟器

1. Introduction

The GaAs-(AlGa)As big photocavity(LOC) laser is a new type appliance which develops on the basis of two kinds of lasers which are single-difference-material junction and two-difference-material junction. It has both the advantage of two-difference-material junction lasers whose threshold electric current is very low and the advantage of single-difference-material junction lasers whose output power is great. So we select this kind of LOC laser as light sources of several kinds of laser simulators. As the output laser beam divergence which is provided by the direction to LOC laser is not very great, the diffraction losses are usually neglected in designing calculations for laser simulators. But in fact the output beam divergence of the LOC laser is rather great and the laser transmission and transformation formulas which are provided by general references can not be used indiscriminately. Thus the diffraction losses of laser simulators are usually quite great and can not be neglected.

2. The divergences of LOC lasers

The divergence curves of the LOC laser which is selected are shown in Fig. 1. In Fig. 1 the

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divergence parallel to p-n junction is 14°, and that normal to p-n junction is 20°. But measured in practice the divergences are much bigger. The typical divergence curves LOC laser which are measured in practice are shown in Fig. 2 and Fig. 3 in which the divergence parallel to p-n junction is 20° and that normal to p-n junction is 66°. But it must be noticed that the above divergences can not be directly used in the laser transmission formulas for the divergences provided by semiconductor lasers are all far-field divergences $\theta_{1/2}$ which are defined at the point of half power. That is $2\theta_{\parallel,1/2} = 20°$, $2\theta_{\perp,1/2} = 66°$. But the divergences provided by general references are far-field divergences θ which are defined at the point of $1/e^2$ of the laser intensity. Thus in order to apply laser transmission formulas $\theta_{1/2}$ must firstly be transformed into θ.

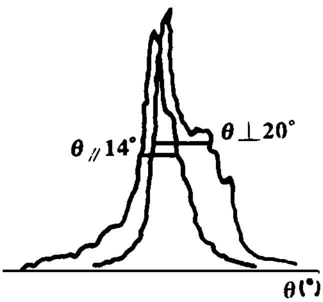

Fig. 1　The divergence angle of light beam

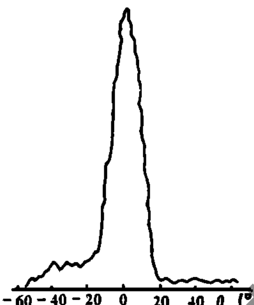

Fig. 2　The typical far-field pattern of LOC laser

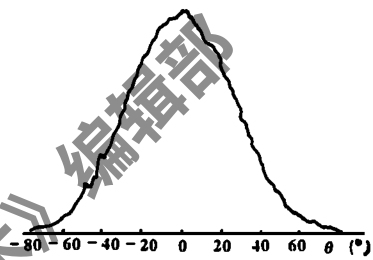

Fig. 3　The typical far-field pattern of LOC laser

3. Transformation of divergences

According to reference [1] the formula by which the divergence defined at the point of $1/e^2$ of laser intensity is transformed into the divergence defined at the point of half power is

$$\theta_{1/2} = \sqrt{\ln 2/2}\,\theta = 0.5887\theta \quad (1)$$

But the author thinks it can not be directly applied here. Because it is only applicable for Gaussian beam which is near transmitting axis. But the divergence of the LOC laser can reach tens degrees. Thus it can not be considered that $\mathrm{tg}\theta = \theta$ and eq. (1) must be modified as

$$\mathrm{tg}\theta_{1/2} = \sqrt{\ln 2/2}\,\mathrm{tg}\theta = 0.5887\mathrm{tg}\theta \quad (2)$$

Substituting $2\theta_{\parallel,1/2} = 20°$, $2\theta_{\perp,1/2} = 66°$ into above equation, we can solve for $2\theta_{\parallel} = 33.3°$, $2\theta_{\perp} = 95.6°$. The divergences are so big, if the transmitting antenna is not used to compress the divergences, the maximum range only reaches m orders of magnitudes. According to reference [2] the maximum range is

$$Z_m = (L/\theta)\exp(-\alpha Z_m/2) \quad (3)$$

In order to meet with the requirement of the maximum reange, θ must be reduced three orders of magnitudes. The relationship among the divergence θ, the focal length f of the transmitting antenna and the laser's maximum transmitting length l is as

$$\theta = l/f \quad (4)$$

l is approximate from tens to hundreds microns, and f is approximate from tens to hundreds millimeters. Thus f is quite long. With the restrictions of cost, volumn, and weight, the two-glued lens whose apertures are not large are used, which makes the diffraction losses be very great.

4. Diffraction losses

The distribution of the energy-flowing density which passes through the Gaussuan beam whose diameter is D and radius is a is

$$S = \mu\mu^* = 2/(\pi\omega_x^2\omega_y^2)\exp\{-2[(x^2/\omega_x^2)+(y^2/\omega_y^2)]\} \quad (5)$$

The ratio T of the power passing through the diameter D to the total power can be derived

$$T = \frac{S_a}{S_\infty} = \int_0^{a/2}\int_0^{a/2}\int_0^{2\pi}\frac{4xy}{\pi\omega_x^2\omega_y^2}\exp\left[-2\left(\frac{x^2}{\omega_x^2}+\frac{y^2}{\omega_y^2}\right)\right]\mathrm{d}x\,\mathrm{d}y\,\mathrm{d}\theta$$

$$= 1-\exp\{-(D^2/4)[(1/\omega_x^2)+(1/\omega_y^2)]\} \quad (6)$$

We call ratio T as power transmission and define the diffraction losses of this aperture as

$$\delta = 1-T = \exp\{-(D^2/4)[(1/\omega_x^2)+(1/\omega_y^2)]\} \quad (7)$$

Table　Diffraction losses for three types of laser simulaters

types	Z_m (km)	f (mm)	D (mm)	a/ω (mm)	a/ω (mm)	T (%)	δ (%)
navigation rocket	1.5	50	28	0.9563	0.2539	61.00	39.00
navigation gun	3.0	100	50	0.8361	0.2267	52.79	47.21
chaser	6.0	200	60	0.5017	0.1360	23.69	76.33

Apparently diffraction losses δ is related to relative diffraction aperture a/ω_x and a/ω_y. If these two relative apertures are 1, then diffraction losses are 13.53%. The smaller the apertures, the bigger the diffraction losses. Now we list the diffraction losses for three types of laser simulators and partial relative parameters in table.

The experimental results for the maximum ranges of three types of laser simulators are fundamentally consistent with the datas in the above table.

Reference

1　周炳琨, 高以智, 陈家骅 *et al*. 激光原理. 北京: 国防工业出版社, 1980: 350

2　ADA 102276, Appendix B

3　于志文. 兵器激光, 1986; (1): 31

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• 产品简讯 •

Nd: YAG 激光器

美国亚利桑那州 Power Technology 公司推出 DY 系列 Nd: YAG 激光器, 该系列激光器设计为宽温度范围运用。内置温差冷却器自动维持苛刻环境中最佳输出时激光器的温度。12V 直流电压装置适用 532nm 波长 0.3, 1.0, 3, 5, 10 和 20mW 输出。轴向束校准和光束中心调整都是标准化的。

中尧　马理　　供稿