DESIGN AND ANALYSIS OF SOME PARAMETERS FOR CO_2 LASER BEAM EXPANDER

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Abstract

In this paper, design analysis and optimization of beam expander device and by using computer software (Zemax). The laser beam source associated with the suggested designs of the optical system is that of the TEA CO_2 laser working at 10.6μm. The optical beam expander is a Galilean design and configured two ZnSe lenses.

Key words: Beam Expander; Optical Design; CO_2 Laser; Range Finder.

Introduction

Application of the lasers in optical systems in the various portions of the spectrum is quite extensive. The lasers coherence, high radiance, and the ease with which it can be modulated have been exploited in various types of optical systems [1]. In particular, laser range finders, beam expanders, and telescopes are of vital importance in the present work (i.e. Forrester and Hulme).

A device that is commonly termed a laser range finder carries out distance measurement to the stationary target through the application of laser [2,3].

Laser range finder has successfully been used in all areas of fire control where target range and direction are parameters, which must be known for the engagement. The laser technology available today allows the development of instruments which are rugged and small enough to be manually portable, and applications in artillery and infantry units have therefore been made possible [4]. One of the first laser range finders deployed in the western world was the Simrad LP3 laser range finder, which has been developed for use by forward artillery observers. It has as effective range (R) from 200 m to 20,000 m and has been adopted as the forward artillery observation instrument in many armies both in Europe and the United States [5].

However, they have been found useful in non-military applications. An example of these is the Contour laser range finder, which is widely used in many fields of engineering. It most significant advantage is mobility and portability, which are very attractive for the users [6,7]. 2- Design Implementation.

The design has been suggested for image forming optical system that has been analyzed with the aid of Zemax software to obtain the desirable design. The optical system shown in Fig.(1) Performs the process of expanding a laser in the transmitter part of the range finder system.

The design is Galilean. Its optical design consists of two lenses, it is used change the properties light beam like: its diameter, divergence angle, and to obtain parallel beam with small divergence for far distance.

Laser beam is focused in small spot size with high intensity especially with pulse lasers. Therefore it is possible to increase and decrease the diameter of laser beam.

(Galilean Design) has these properties:

1- Its Consists of two lenses, on of them is positive objective lens, and the other is negative eye lens.
2- The distance between them is d, it is calculate of with equation

$$d = BFL + EFL \quad \text{.......................................(1)}$$

where

BFL: the back focal length of objective lens.

EFL: the effective focal length of eye lens.

$$EFL = \frac{y_t}{u_t} \quad \text{...(2)}$$

where

y_t: the height of incident aperture ray on the optical surface.

u_t: the aperture ray form with the optical axis angle.

t : the number of the optical surface.

The refractive index of the lens is 2.403 for (ZnSe) that is used in beam expander.

The magnification for beam expander is calculated by:

$$M = \frac{D_{out}}{D_{in}} = \frac{f_{out}}{f_{in}} = \frac{\theta_{in}}{\theta_{out}} \text{ ....(3)}$$

where

D_{out} : the diameter of output beam.

D_{in} : the diameter of input beam.

f_{out} : the focal length of output lens.

f_{in} : the focal length of input lens.

θ_{in} : the divergence angle of input beam.

θ_{out} : the divergence angle of output beam.

For primary design of beam expander this procedure must be followed:

1- In design of objective lens by take good radius of curvatures is taken into account by using (Zemax) program; the process begins by assuming R_1 and R_2 then varying R_1 and keeping R_2 constant until the lowest possible divergence angle is obtained then R_1 is kept constant at optimization value and R_2 varies until the lowest possible divergence angle is leached, we have optimization lens then focal length for this lens is found, and optimum image is obtained by one lens but it is not free from spherical aberration. This is clearly shown in Table (2).

The abbreviations OBJ, STO, and IMA listed in Surface column represent the object, stop aperture, and image respectively. In Table (2) Object represents laser beam, Stop aperture represents first surface of lens, 2 represents second surface of lens, and IMA represents image formation on target.

The Radius column in Table (2) represents the radius of curvature of a lens. Infinity indicates for a plane surface i.e. a surface whose radius of curvature is infinite. The minus (-) and (+) signs indicate a concave and convex surfaces respectively for the lens under consideration.

Thickness column represents the separation between surfaces. For example, the thickness of surface STO is equal to 10 mm; it is the axial separation between the stop aperture (STO) and the next surface (surface 2) which is the second surface of lens.

Glass column contains the type of glass materials used in the lens design process. The blank in this column indicates that the region is occupied by air.

Semi-diameter column refers to the value of the lens aperture radius in millimeters. For example, surface 2 has a semi-diameter equal to 10 mm, thus the diameter of the lens aperture is equal to 20 mm.

2- To remove spherical aberration which is appearing by large area in image beam on target we make optimization for lens properties through change in radius of curvatures and its focal length many times to obtain lens with little spherical aberration. That is clearly shown in Table (3).

Design eye lens by taking good radius of curvatures by using (Zemax) program; the process begins by assuming R_1 and R_2 then varying R_1 and keeping R_2 constant until divergence angle is obtained then we keep R_1 constant at optimization value and vary R_2 until the divergence angle is obtained so, we have optimization lens and then find focal length for this lens. This is clear in Table (4).

Now, we put eye lens to obtain beam expander. Then we must change distance between two lenses for many times to obtain parallel output laser beam which is, condition of beam expander but if we don't obtain parallel output beam that is not beam expander and we must try again. So, we assume magnification is 3 by according to the laser input angle 1.35 mrad and computation from magnification law. But after optimization for two lenses to obtain parallel beam from beam expander magnification is change caused by optimization then it become 2.86. This is clearly shown in Table (5).

5-To obtain magnification 3 then we change focal length for eye lens in proportion to objective lens. By using this method

We have laser beam has which 1.35 mrad divergence angle and 5 mm diameter. So, to obtain best case for beam expander we must reduce divergence angle and increase beam diameter. By using :

$$M = \frac{\theta_{in}}{\theta_{out}} \text{ ....(4)}$$

$$\therefore \theta_{out} = 0.45 \text{ mrad} = 0.025^{\circ}$$

$$M = \frac{D_{out}}{D_{in}} \qquad (5)$$

$$D_{out} = 15 \text{ mm}$$

Eye lens must be smaller three-times than objective lens to satisfy optimum description for beam expander. This is clearly illustrated in Table (6).

Parameters Considerations

These parameters are studied for each case of design.

These parameters are:

Spot diagram: The ray density has a maximum value based upon the number of fields displayed, the number of wavelengths defined, and available memory. Focus spot diagrams will trace half of the maximum number of rays possible on standard spot diagrams.

Wavefront Map: displays the wavefront aberration.

For all cases of beam expander:

a- for two lenses (beam expander m=2.86).

b- for two lenses (beam expander m=3).

Conclusion

The field of view is small and divergence angle for beam expander (0.45 mrad), therefore the spherical aberration appears small.

In this design, we can reduce of divergence angle (0.45 mrad) and increase diameter (15 mm) for beam expander to obtain three times magnification.

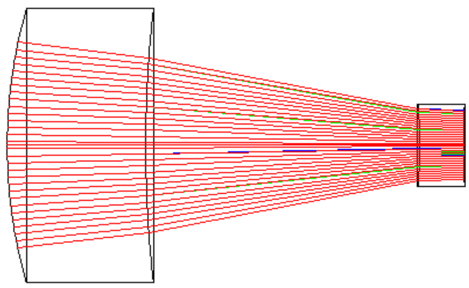


Fig.(1) : Two lenses for Beam Expander.

Table (1)
Is explain these parameters.

Eye lens (negative)		Objective lens (positive)		thick		D_{opt}		D_{real}		M	θ_{in} (mrad)	θ_{out} (mrad)	f
R_1	−32.73	R_1	36.76	10	3	2(	9	22	11	3	1.35	0.45	100
R_2	46.08	R_2	89.67										

Table (2)
Initially proposed data of beam expander lens (All dimensions in millimeters).

Surf. Type		Radius		Thickness		Glass Material type		Semi-Diameter	
OBJ	Standard	Infinity		Infinity				Infinity	
STO	Standard	67.309649		10.000000		ZnSe		10.000000	U
2	Standard	−495.814060		38.990898	M			10.000000	U
IMA	Standard	Infinity						0.192259	

Table (3)
Data on beam expander lens after optimization (All dimensions in millimeters).

Surf. Type		Radius		Thickness		Glass Material type		Semi-Diameter	
OBJ	Standard	Infinity		Infinity				Infinity	
STO	Standard	36.761076	V	10.000000		ZnSe		10.000000	U
2	Standard	89.674960	V	33.649631	M			10.000000	U
IMA	Standard	Infinity						0.094023	

Table (4)
Data on beam expander eye lens (All dimensions in millimeters).

Surf. Type		Radius		Thickness		Glass Material type		Semi-Diameter	
OBJ	Standard	Infinity		Infinity				Infinity	
STO	Standard	–32.730868		3.150000		ZnSe		2.863092	U
2	Standard	46.085283		–14.082335	M			2.863092	U
IMA	Standard	Infinity						2.712764	

Table (5)
Data on optimization beam expander magnification is 2.86
(All dimensions in millimeters).

Surf. Type		Radius		Thickness		Glass Material type		Semi-Diameter	
OBJ	Standard	Infinity		Infinity				Infinity	
STO	Standard	36.761076		10.000000		ZnSe		10.000000	U
2	Standard	89.674960	V	19.130500				10.000000	U
3	Standard	–34.296000	V	3.300000		ZnSe		2.782562	
4	Standard	48.289000		21439.719541	M			2.678468	
IMA	Standard	Infinity						135.176807	

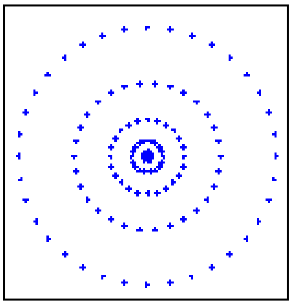
Table (6)
Data on optimization beam expander magnification is 3
(All dimensions in millimeters).

Surf. Type		Radius		Thickness		Glass Material type		Semi-Diameter	
OBJ	Standard	Infinity		Infinity				Infinity	
STO	Standard	36.761076	V	10.000000		ZnSe		10.000000	U
2	Standard	89.674960	V	19.784550				10.000000	U
3	Standard	–32.730000		3.150000		ZnSe		3.000000	U
4	Standard	46.085000		–2427637.3149	M			3.000000	U
IMA	Standard	Infinity						5704.185657	

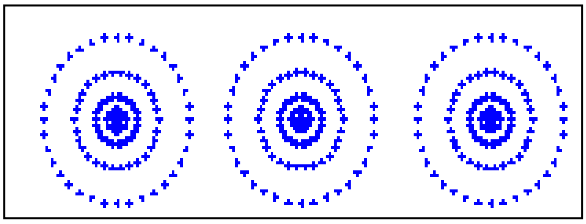
The specification of the beam expander system is given in Table (7).

Table (7)
General lens data.

Surfaces	5
Stop	1
System Aperture	Entrance Pupil Diameter = 15
Effective Focal Length	-7283487 (in air)
Effective Focal Length	-7283487 (in image space)
Back Focal Length	-2427637
Total Track	2427637
Image Space F/#	485565.8
Image Space NA	1.029691e-006
Stop Radius	7.5
Paraxial Image Height	3178.021
Paraxial Magnification	0
Entrance Pupil Diameter	15
Field Type	Angle in degrees
Maximum Field	0.025
Primary Wave	10.6
Lens Units	Millimeters
Angular Magnification	3.000248



(b) Field = 1, 2, 3
RMS Radius = 1.5E+006, 1.5E+006, 1.5E+006
GED Radius =2.5E+006, 2.5E+006, 25E+006
Scale bar = 1E+007
OBJ = 0.025, 0.0125, 0.00 DEG
IMA = -3178.024, -1589.011, 0.00 mm
Surface = 5



(b) Field = 1, 2, 3
RMS Radius = 1.5E+006, 1.5E+006, 1.5E+006
GED Radius =2.5E+006, 2.5E+006, 25E+006
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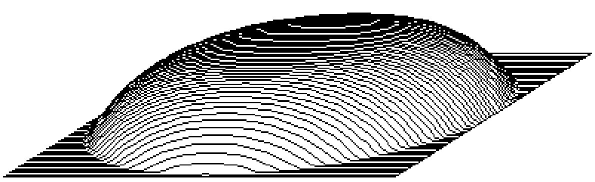
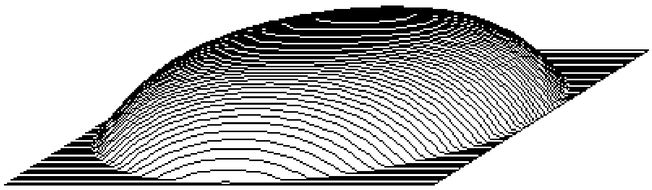
IMA = -3178.024, -1589.011, 0.00 mm
Surface = 5



(a) 10.6μm at 0.1 DEG
Peak to Valley is 0.0790 Waves



(b) 10.6μm at 0.025 DEG
Peak to Valley is 0.0604 Waves

Fig. (1) : Spot Diagram for 10.6 μm, Reference: Chief Ray, Wavelength: All, Field: All, Pattern: Hexapolar, Color Rays By: Waves, Ray Density: 6.

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الخلاصة

في هذا البحث تم تصميم موسع حزمة الليزر والذي يمثل المنظومة البصرية في هذا التصميم والتي تم تحليلها باستخدام نظام Zemax البرمجي للحصول على أفضل تصميم باستخدام حزمة ليزرية ذات شدة عالية.ان النتائج التي تم الحصول عليها من خلال دراسة متغيرات موسع الحزمة أثبتت إمكانية تقليل الزيغ الكروي من خلال إضافة عدسات إلى التلسكوب البصري بالاعتماد على التحليل البرمجي لنظام Zemax.