Evaluating The Cumulative Line Spread Function For ZnSe Infrared Material In The Optical Design of Lenses

A. R.A.S. Mohamad , R. S. Abass
Ministry of Technology and Science.
Department of physics ,College of Ibn-Al-Hitham University of Baghdad

Abstract

The present research aims to study the efficiency of infrared material lenses compared with the glass material lenses by determining LSF and CLSF for perfect optical system having circular aperture, Amorphous(1,2) material transmitting infrared radiation (AMTIR) is used for infrared window, lenses and prisms when transmission in the range of 1-14 μm is desired in application like thermal imaging, astronomical and forward looking infrared (FLIR), AMTIR is the low thermal change in refractive index 72 * 10^{-6} /C ^{O} is an advantage in lenses design to prevent defocussing.

Introduction

The optical system can actually contain any number and combination elements, mirror, prisms, rotating polygon scanners, filters and sorts of optical components(3).Chemically vapor deposited(2) (CVD) zinc selenide (ZnSe) is the material of choice for our studying that is used as optical components in high powered Co_2 lasers due to its low bulk absorption at 10.6 microns. Its index of refraction homogeneity and uniformity offers excellent material has been used as small windows and lenses in medical and industrial applications such as thermometry and satellite. There are two kinds for testing efficiency of image formed by lenses are qualitative and quantitative, the later is comprised of testing photometry where involving of determination methods of line spread function LSF and cumulative line spread function CLSF. The LSF know by generally was description of intensity distribution in image plane and its function of lateral distance for image plane, Ander(4) was the firsts of studied line spread function.

Ahmed (5) considers the image formed by circular aperture for incoherent line sources posit on axis u=0 for image plane. And the LSF was given by :

$$L(\bar{u}) = \int_y \left| \int_x f_{(x,y)} e^{i2\pi\bar{u}x} dx \right|^2 dy$$

but CLSF is cumulative summation for LSF and can be determined by form

$$I = \int_{-\infty}^{\infty} L_{(\bar{u})} d\bar{u} = \int_{\bar{u}} \int_y \left| \int_x f_{(x,y)} e^{i2\pi\bar{u}x} dx \right|^2 dy\, d\bar{u}$$

$$= \int_y \int_x \int_{x_1} f_{(x,y)} f^{*}_{(x_1,y)} dx dx_1 dy \int e^{i2\pi\bar{u}(x-x_1)} d\bar{u}$$

but Dirac – delta function => $\int e^{i2\pi\bar{u}(x-x_1)} d\bar{u} = \delta_{(x-x_1)}$

$$= \int_y \int_x f_{(x,y)} dx\, dy \int_{x_1} \delta_{(x-x_1)} f^{*}_{(x_1,y)} dx_1$$

but $\int_{x_1} \delta_{(x-x_1)} f^{*}_{(x_1,y)} dx_1 = f^{*}_{(x_1,y)}$

$$CLSF = L_{(z)} = \int_y \int_x \left| f_{(x,y)} \right|^2 dx\, dy$$

Where x, y coordinate out put pupil function. x_1, y coordinate complex conjugate.

$\bar{u}, \bar{v}$ coordinate image plane, z lateral distance from the center of the optical axis.

Theoretical details : Provisionally paper we consider the image formed by circular aperture for incoherent line source and perfect optical system. (CVD) ZnSe material thin lenses under studying we selected wave length(2) at 4 μm correspond to index refractive value 2.4 in order to study the transmitting motors satellite at range 3-5 μm by this technique as shown in fig.(1),however,glass material lenses at visible range correspond to 1.5 index refractive. The (6) radius is constant 150 mm. LSF was studied by determination of ray tracing (7) where containing of:

(1)-Transfer equation.

$$\bar{x} = x - \frac{x}{r}\left[\frac{x^2 + y^2}{(x^2 - y^2)/r + \left((x^4 - 2x^2y^2 + y^4)/r^2 + x^2 + y^2\right)^{1/2}}\right]$$

and so that

$$\bar{y} = y - \frac{y}{r}\left[\frac{x^2 + y^2}{(x^2 - y^2)/r + \left((x^4 - 2x^2y^2 + y^4)/r^2 + x^2 + y^2\right)^{1/2}}\right]$$

(2)-Refraction equation.

Where $\bar{L}, \bar{M}$ are direction – cosine

$$\bar{L} = \left[\frac{-nx}{r} - \frac{\bar{x}}{r}\left[\left(\bar{n}^2 - n^2(1 - \cos^2 I)\right)^{1/2} - n\cos I\right]\right] \Big/ \bar{n}$$

$$\bar{M} = \left[\frac{-ny}{r} - \frac{\bar{y}}{r}\left[\left((\bar{n}^2 - n^2(1 - \cos^2 I)\right)^{1/2} - n \cos I\right]\right] \Big/ \bar{n}$$

Where x, y coordinates objective plane & $\bar{x}, \bar{y}$ coordinate image plane, r is radius of curvature for lens, n refractive index of air, ń refractive index of material lens, I is the angle of incident rays. The calculation results of refraction equation are plotted graphically using best fit method and as shown in fig.(2,3,4,5)

Results and Discussion

Some interesting features of these results will be discussed in this paper.fig.(2,3) are illustrate the relation between LSF and lateral distance for image plane z formed by IR and glass lenses successively and we note the distribution intensity with values z are equivalence in fig.(2,3) showing that intensity in ZnSe material greater than for glass lenses and these concern efficiency of ZnSe material lenses, fig.(4,5) are represent curves of CLSF with values z by statistical form once and by cumulative LSF another one. We show the maximum intensity is unity at reduced coordinates 'Z=0 and the maximum energy concentration in image plane formed by ZnSe lenses.

References

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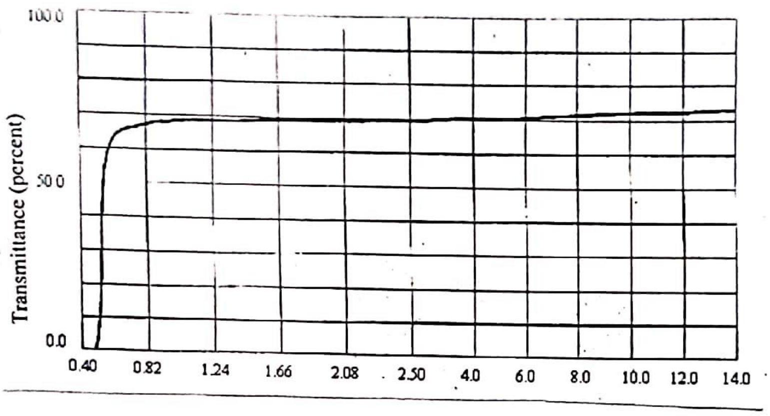


Wave length (micron)

Fig .(1) CVD Zinc Selenide Transmission

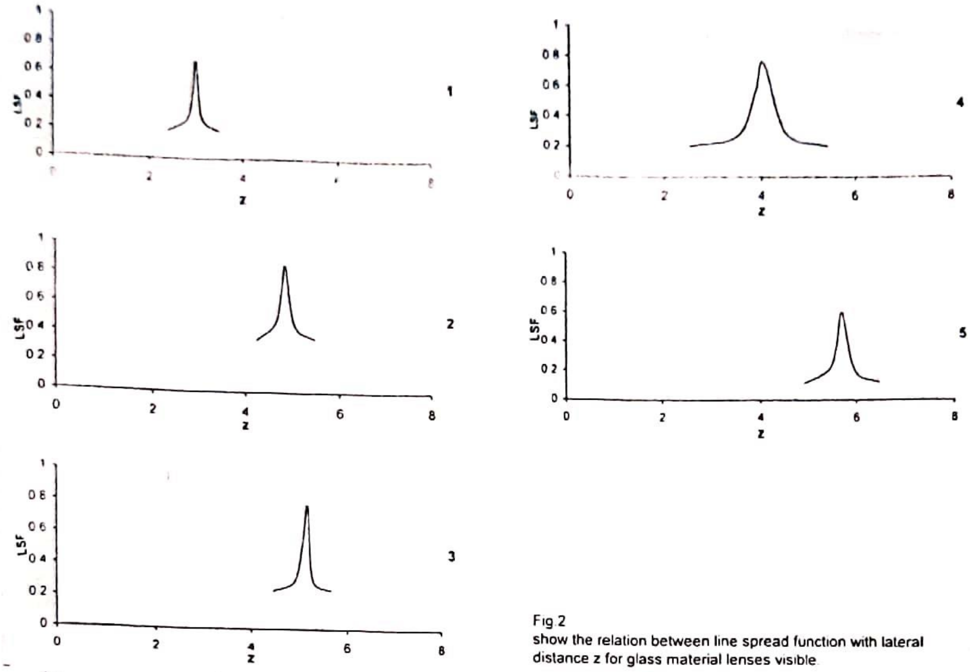


Fig 2
show the relation between line spread function with lateral distance z for glass material lenses visible

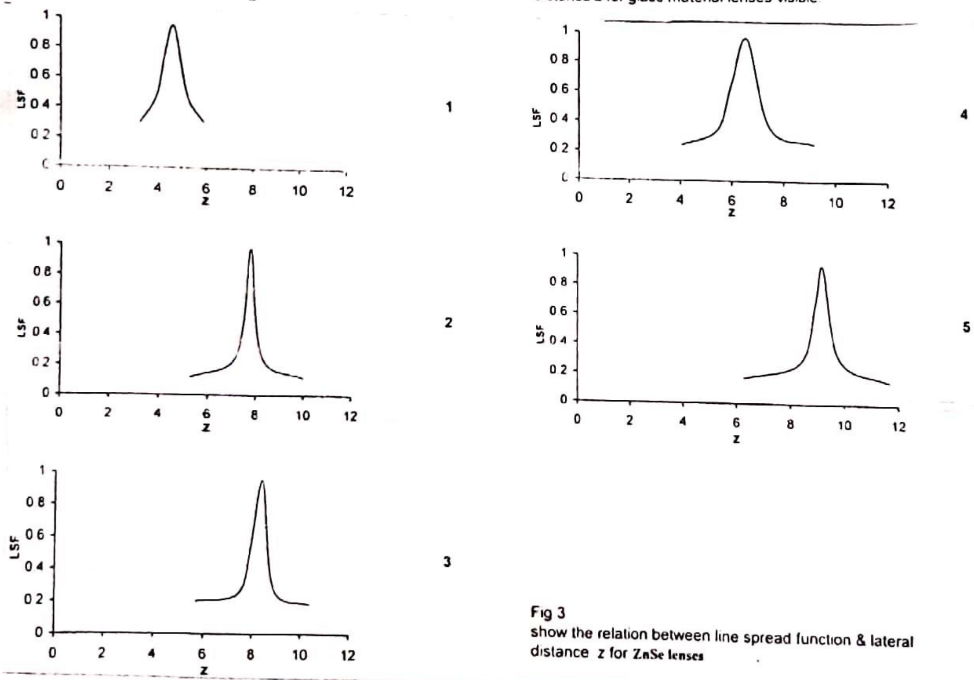
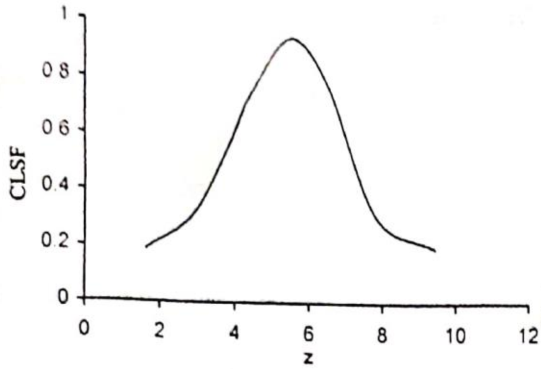
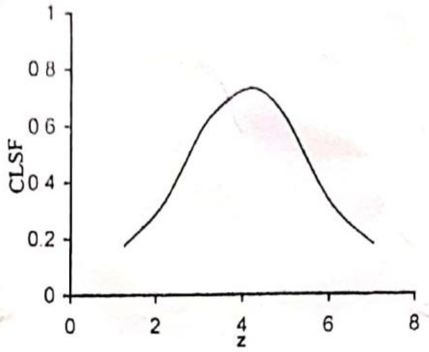


Fig 3
show the relation between line spread function & lateral distance z for ZnSe lenses



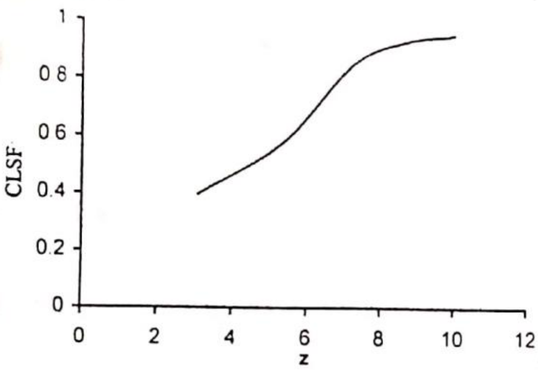
(a)

Fig.5
Show CLSF with lateral distance z for ZnSe lenses
(cumulative form)



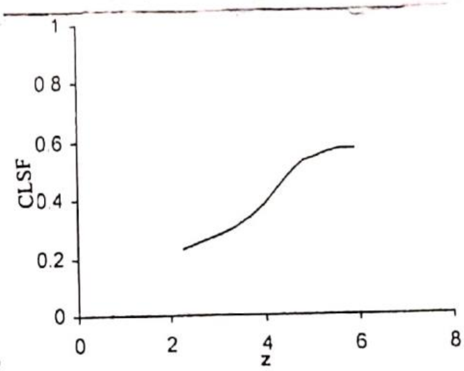
(a)

Fig.4
Show CLSF with lateral distance z for glass lenses
(cumulative form)



(b)

Fig.5
Show CLSF with lateral distance z for ZnSe lenses
(statistical form)



(b)

Fig.4
Show CLSF with lateral distance z for glass lenses
(statistical form)

حساب دالة الانتشار الخطية التراكمية للمادة ZnSe تحت الاحمر

عبدالرزاق عبدالسلام محمد ، رغـد صبحي عباس
وزارة العلوم والتكنولوجيا
قسم الفيزياء ،كلية التربية- ابن الهيثم ، جامعة بغداد

الخلاصة

يهدف البحث لدراسة كفاءة العدسات المصنعة من مادةZnSe التي تعمل بمدى الاشعة تحت الاحمر ومقارنتها مع عدسات مصنعة من الزجاج، وذلك عن طريق حساب دالة الانتشار الخطية LSF ودالة الانتشار الخطية التراكمية CLSF لنظام بصري مثالي ذو فتحة دائرية .

المواد ذوات التركيب العشوائي والنافذ للاشعة تحت الاحمر AMTIR تستخدم في صناعة النوافذ البصرية والعدسات والمواشير، وذلك لان نفاذيتها مرغوب فيها في المدى من $1-14\mu m$ للحاجة لها في تطبيقات مثل التصوير الحراري ،المركبات الفضائية والترقب بالاشعة تحت الاحمر وتستخدم مواد AMTIR في تصميم العدسات كونها تمتاز بالتغير الحراري الواطيء لمعامل انكسارها $72 * 10^{-6} /C^{O}$ مما يجعلها مفيدة في منع اللابؤرية .