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DESIGN AND ANALYSISA ZOOM CASSEGRAIN TELESCOPE COVER MIDDLE IR REGION USING ZEMAX PROGRAM

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ABSTRACT

The goal of the project is to find an optimal design of zoom -Cassegrain telescope which is popular for amateur astronomers. Also,the objective function of the optical design is to reduce the aberrations to provide aclear image. Cassegrain telescope has been designing and analysis by using (Zemax) software. The full field of view of the objective lens angle to 0.383°, the focal length to 747,748,750 and751mm, Back focal distance BFD 41 mmand Entrance pupil diameter 218.The system consists of a fixed focal length of the objective lens, zoom eyepiece. The eyepiece continuous zoom the zoom telescope system especially Cassegrain the zoom telescope system applications a wide range of zoom optical system .Wide range of wavelength extends from (3.2--4.2µm) and diffraction limited over a large field of angles with F/#3.4 also studied. We find that less aberration that hasbeenreached in the design values are(±0.5 to ±2.2) µm.

KEYWORDS: Cassegrain telescope, DesignCassegrain, ZoomCassegrain, Telescope Infrared.

I. INTRODUCTION

Early forms of zoom lenses were used in optical telescopes to provide continuous variation of the magnification of the image, and this was first reported in the Proceedings of the Royal Society in 1834. Can using the zoom only a few kilometers, or it can extend to 100 kilometers or more. Accurately imaging a missile trajectory under these changing conditions requires either multiple imaging systems with fixed focal lengths or a zoom lens system that is capable of changing its magnification to accommodate the variation in object distance. A zoom system offers significant advantages in that it eliminates the need for multiple setups of the test equipment or the time-consuming and costly task of changing fixed imaging systems during the tests. In addition, the use of a single zoom lens system can eliminate the need for an inventory of multiple imaging systems, thereby reducing the costs and logistics of carrying multiple systems in inventory [1].Combines infrared telescope infrared (heat) of the space objects. Most telescopes infrared reflective optical telescopes, equipped with detector instead of the eyepiece.And gives any object, which is at room temperature, large amounts of infrared radiation due to the heat that keeps them. Infrared light has fairly long wavelengths that pass through clouds of dust betterthan light with shorter wavelengths. Infrared telescopes are used to observe objectssurrounded by dust, such as young stars being born inside nebulae. Because allwarm objects give off infrared light, infrared telescopes are chilled so that theywon't detect their own glow. The lifespan of an infrared telescope is limited by howlong the telescope can be kept cool[2].We choose aCassegrain system because of higher throughput and ease of fabrication and assembly in addition to our confidence in maintaining alignment in a rugged environment, take advantage of the heat can be captured effectively, such as a mammal, cars, etc., of great benefit in the military.

II. THEORY

Cassegrain telescopes are optical telescopes that combine specifically shaped mirrors and lenses to form an image. This is usually done so that the telescope can have an overall greater degree of error correction than their all lens or mirror counterparts with a consequently wider aberration free field of view. Their designs can have simple all spherical surfaces and can take advantage of a folded optical path that reduces the mass of the telescope, making them easier to manufacture [3]. A mirror has substantially less spherical aberration than a lens of equivalent focallength. In addition, the spherical aberration of a concave mirror is opposite in sign tothat of a positive lens. Therefore, several researchers have proposed the use of a weak negative lens in conjunction with a concave mirror.Proposeda weak aspheric corrector at the center of curvatureof a spherical mirror.In the

Cassegrain system, two mirrors are required. The primary has a hole in itand the smaller secondary is attached to (or is actually a part of) one of the frontcorrector lenses. Due to vignette, fields of view are generally limited to about 158.The computer program must have the following features [4]:

1. Surface radii, material, and thickness must be capable of being tied or setequal to another surface.
2. Axial distances from one surface to another must be capable ofbeing bound.
3. Beam diameter at the secondary mirror has to be limited.
4. Delete tracing of the chief ray and other rays that will ultimately beblocked by the central obscuration.

These lenses use some form of the Cassegrain design which greatly reduces the physical length of the optical assembly, partly by folding the optical path, but mostly through the telephoto effect of the convex secondary mirror which multiplies the focal length many times (up to 4 to 5 times) This creates lenses with focal lengths from 250 mm up to and beyond 1000 mm that are much shorter and compact than their long focus or telephoto counterparts.An infrared ray is a form of electromagnetic radiation the same as radio waves, microwaves, ultraviolet rays, visible light, X-rays, and gamma rays. All these forms, which collectively make up the electromagnetic spectrum, are similar in that they emit energy in the form of electromagnetic waves traveling at the speed of light. The major difference between each ‘band’ in the spectrum is on their wavelength, which correlates to the amount of energy the waves carry. For example, while gamma rays have wavelengths millions of times smaller than those of visible light, radio waves have wavelengths that are billions of times longer than those of visible light.The ratio of feature sizes in an image (d_{image}) to the sizes of the features in a resolution target (d_{object}) since the focal length (for an object at infinity) of a lens under test is related to the focal length of a collimator (testdoublet) by[5, 6].:

$F = \frac{d_{image}}{d_{object}} . F_{collimator}$,the spacing, t, between the two lenses will be equal to the sum of the focal length of the lenses. $t = f1 + f_2$ the simplest version of a relay lens would be a biconvex lens inserted between the input and output lenses, such that distance between the input lens and the relay lens is$t_{r1} = f_1 + 2f_{r1}$ and the distance between the relay lens and the output lens is $t_{r2} = 2f_{r2} + f_2$, Where, f_{r1} and f r2 are the relay lens focal lengths. The hyperbolic mirror then reflects those light rays to its other focus, where the image is observed. The radii of curvature of the primary and secondary mirrors, respectively, in the classic configuration are:

$$R_1 = \frac{2DF}{F-B} \dots\dots\dots\dots\dots\dots (1)$$

$$R_2 = -2DF/(F-B-D) \dots\dots\dots\dots (2)$$

Where: F:is the effective focal length of the system, B:is the back focal length of the distance from the secondary to the focus ,D:is the distance between the two mirrors.

If instead of B and D the know quantities are the focal length of the primary mirror $F_1$and the distance to the focus behind the primary mirror b, Then $D=F_1$ (F-b)/ $(F+F_1)$ and B=D+b .The conic constant of the primary mirrors is that of parabola $K_1=-1$And that of the secondary mirror,$K_2$is chosen to shift the focus to the desired location:

$$K_2 = -1 - \alpha - \sqrt{\propto (\propto + 2)} \dots\dots\dots\dots\dots\dots\dots \quad (3)$$

Where

$$\propto = \frac{1}{2}\left[\frac{4DBM}{(F+BM-DM)(F-B-D)}\right]^2 \dots\dots\dots\dots (4)$$

Focal Ratio: An important system performance parameter considered with all telescope is the focal ratio. The focal ratio is a ratio of the focal length of a mirror and the diameter of the aperture. Most telescopes are designed with a focal ratio specified, however for your model the focal ratio will be calculated from the radius of curvatures of the mirrors and the separation in-between mirrors.

$$\frac{1}{f'} = \frac{-f_2{}' + f_1{}' - Z_{mirror}}{f_1{}' f_2{}'} \dots\dots (5)$$

$$\frac{F}{\#} = \frac{EFL}{D} \quad \dots\dots\dots\dots\dots (6)$$

Where: f is Focal length of telescope, f1 is Focal length of primary mirror, f2 is Focal length of secondary mirror, Z mirrors Distance between primary and secondary mirrors, $\frac{F}{\#}$ is $\frac{\text{Focal}}{\#}$ of Cassegrain Telescope, D is Diameter of Cassegrain corrector.

III. DESIGN AND DISCUSSION

Table (1) consists of the number of surfaces for thelens, theradius of curvature, thickness and types of glass also using the aperture value of theobjective lens. Therefore, from all the input data above we can see the results of the design as in below. The Cassegrain Telescope consists of two mirrors and a set of lenses that collect light at the center. Through the use of a range of different lenses shape with the appropriate choice of materials Glass lenses (with coefficients of refraction different), can thus avoid the disruption of radiation collected , (if you do not choose the lenses right leads to the production of the image is not clear bad contrast or separate colors of light in the picture The resulting,or Alachtlalin happen together).Fig (1) a set of lenses used and consists of twelve surface made of three materials are ZNS, GERMANIUM, and SILICON, confined within a wavelength of (3.2--4.2) µm. table -1,consists of twenty-six surfaces, the different types of metal softens so that all the input data that represented in the figure below.This table consists of the number of surfaces for alens which have three surfaces, radius of curvature, thickness and types of glass also using the aperture value of theobjective lens. Therefore, from all the input data above we can see the results of the design as in below.

Table (1) the Zoom Cassegraindesign[12].

SURF -- TYPE		**RADIUS**	**TICKNESS**	**GLASS**	**DIAMETER**
OBJ	**Standard**	**INFINITY**	**INFINITY**		**0**
1	**Standard**	**2318**	**20**	**ZNS**	**240**
2	**Standard**	**INFINITY**	**222**		**240**
3	**Standard**	**-552**	**29**	**ZNS**	**209**
4	**Standard**	**-672**	**0**	**MIRROR**	**214**
5	**Standard**	**-672**	**-29**	**ZNS**	**214**
6	**Standard**	**-552**	**-212**		**205**
STO	**Standard**	**-369**	**177**	**MIRROR**	**61**
8	**Standard**	**-2013**	**6**	**GE**	**25**
9	**Standard**	**-133**	**3**		**25**
10	**Standard**	**-152**	**6**	**SI**	**25**
11	**Standard**	**140**	**196**		**25**
12	**Standard**	**99**	**7**	**SI**	**70**
13	**Standard**	**911**	**16**		**70**
14	**Standard**	**-149**	**4**	**GE**	**52**
15	**Standard**	**INFINITY**	**32**		**70**
16	**Standard**	**61**	**7**	**GE**	**43**
17	**Standard**	**46**	**1**		**36**
18	**Standard**	**49**	**8**	**SI**	**43**
19	**Standard**	**98**	**20**		**43**
20	**Standard**	**INFINITY**	**4**	**SI**	**22**
21	**Standard**	**65**	**22**		**22**
22	**Standard**	**180**	**6**	**SI**	**22**
23	**Standard**	**-77**	**1**		**22**
24	**Standard**	**-51**	**6**	**GE**	**22**
25	**Standard**	**-63**	**40**		**22**
IMA	**Standard**	**INFINITY**	**-**		**10**

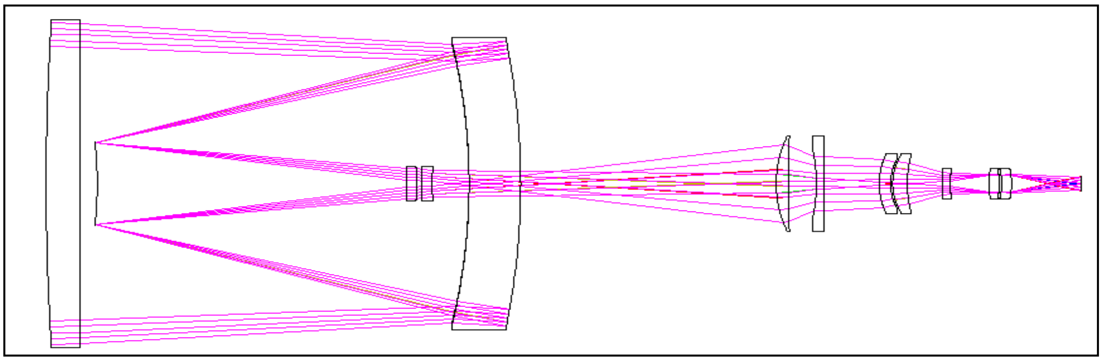


Fig.(1) The structure of the Zoom Cassegrain[12].

The angular size of an image measured using a theodolite looking through the zoom lens and onto the focalplane. The focal length of the lens is given by$F = \frac{\Delta x}{\tan\theta}$, Where$\Delta x$ is the distance between two points on the image and $\theta$is the angle between the points.Divergence angle of a collimated beam passing through the lens since the f-number of the lens is related to. The divergence half-angle (θ) and the diameter of the entrance aperture (D) by: $F = \frac{D}{2\sin\theta}$. Power = ∅ =1/ (focal length), and curvature = (1/radius) is another.If we know the radii of the two surfaces, R1 and R2, and the refractive index, n, we find that

$$\emptyset = \frac{1}{\text{focal length}}(n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

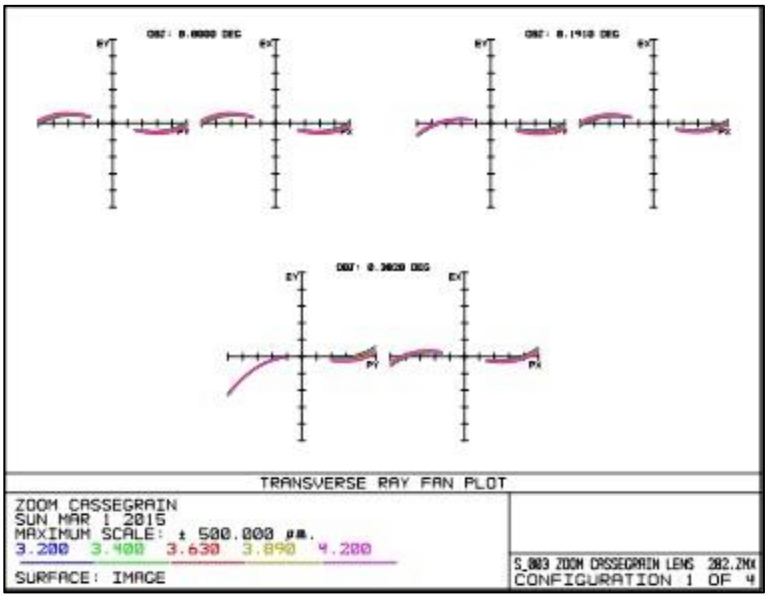
If the distances from the object to the lens and from the lens to the image are S1 and S2 respectively, for a lens of negligible thickness, in theair, the distances are related by the thin lens formula:

$$.\frac{1}{S_1} + \frac{1}{S_2} = \frac{1}{f}, \; M = f2/f1 = R2/R1 = h2/h1$$

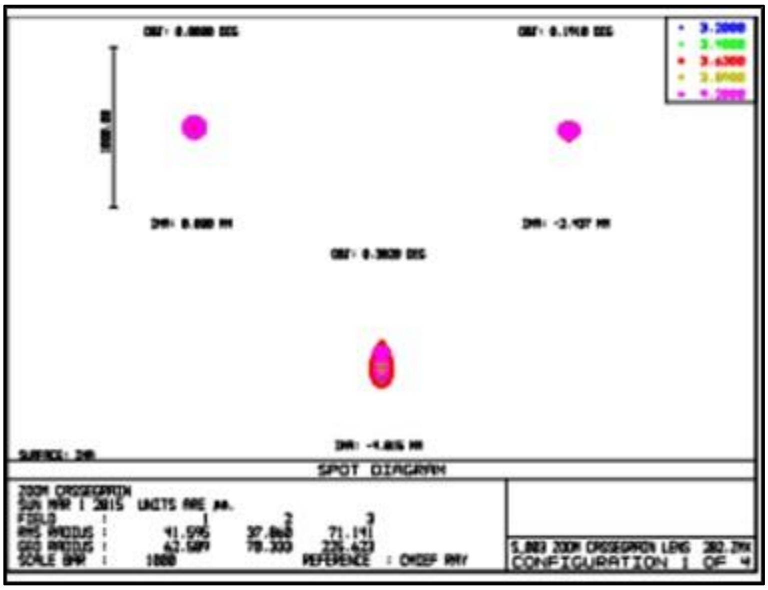
Where, M is the magnification, f2 = effective focal length of exit lens, f1 = effective focal length of entry lens, R2 = radius of curvature of exit lens, R1 = radius of curvature of entry lens, h2 = radius of exit spot (image height), h1 = radius of entry spot (object height) .

GENERAL TELE. DATA

- **Surfaces=26**
- **Effective focal length = EFL =750 mm**
- **Back focal distance = BFD = 41 mm**
- **Entrance pupil diameter=218**
- **Image space f/# = 3.4**
- **Field angles = 0°, 0.191°, 0.383°**
- **Wavelength = 3.2--4.2µm (d light)**
- **Total mass=9237mm**
- **Focal length=747,748,750,751,751.**

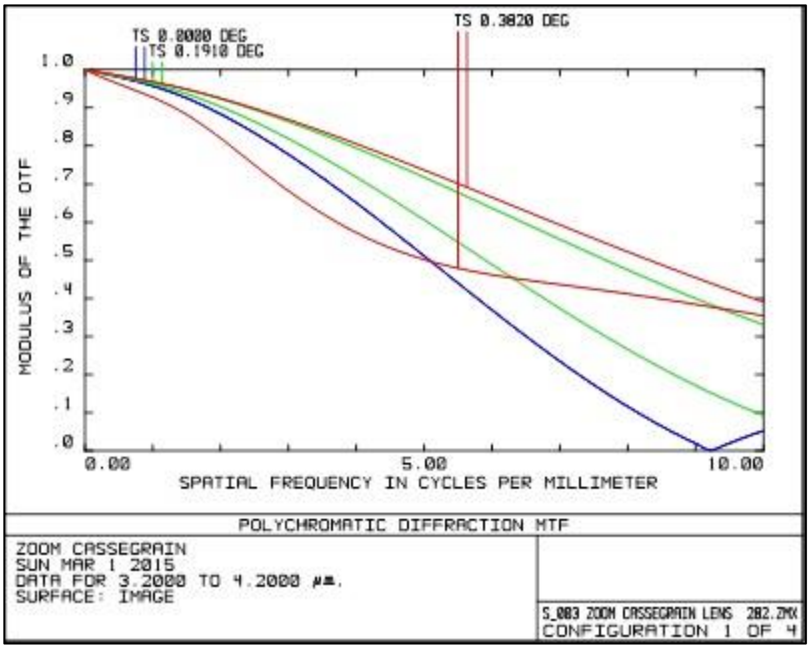


Fig(2) the transverse ray fan plot[12]



Fig(3) spot size diagram[12].

For Fig (2) we can see that the aberration for the lenses design of Zoom Cassegraincan be represented by the figures in each design consider the ray intercept curves in fig-2, shows that transverse ray aberration of rays from an axial object point.Spot diagrams are the geometrical image blur formed by the lens when imaging a point object. This is a more functionally useful form of output; however, it is sometimes difficult to distinguish the specific aberrationsPresent.Another method of obtaining information about the aberration of a lens is to plot spot diagrams. The atypical output from a spot diagram calculation is shown in Fig-3. The results of eyepiece lens as the first design are used here. Each set in Fig-3, in the fig-3, shows the number of light spots where each one of these spots represents entry rays within the design above. In the event that the field is zero, namely that, all very close to the rays axis of the optical spot size is virtually free of defects The value of half a square spot rate, But when the fall of the field of radiation on the visual system, the optical spot as shown in the figure show their flaws, but within the allowable. We have in the figure above three fields of RMS radius see Fig (3) found as 41.595, 37.860 and 71.141 microns. From the above figures notice that the spot size and transverse rays are nearly coincident in thefield of curvature in the fig.(2, 3) That means the aberration in this lens is very little.



Fig(4)MTF and Simulated Bar Target Imagery of Zoom Cassegrain[12].

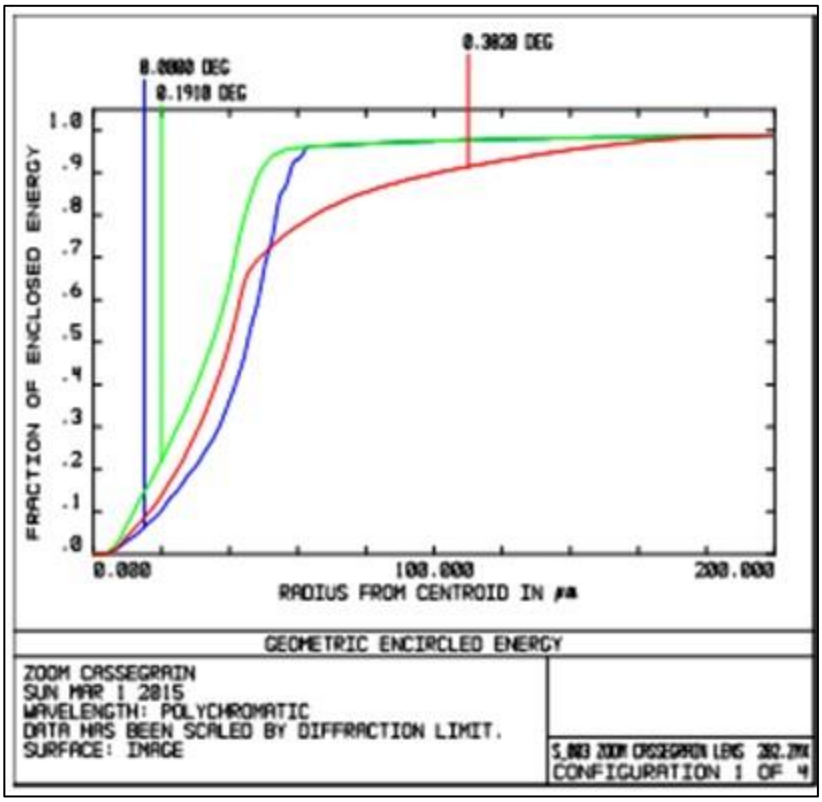


Fig (5) Encircled Energy forZoom Cassegrain[12]

MTF is perhaps the most comprehensive of all optical system performancecriteria, especially for image forming systems. Fig (4) is a representationof what is happening. We begin with a periodic object or target,which is avarying sinusoid ally in its intensity and value spatial frequency in cycle's millimeter 10. This target is imaged by thelens under test, and we plot the resulting intensity pattern at the image.Due to aberrations, diffraction, assembly and alignment errors, and other factors.

Encircled energy is energy percentage plotted as a function of imagediameter,as the circle increases in radius, more of the PSF energy is enclosed until the circle is sufficiently large to completely contain all the PSF energy. Fig (5) the encircled energy curve thus ranges from zero to one.A typical criterion for encircled energy (EE) is the radius of the PSF at which either 50% or 80% of the energy is encircled. This is a linear dimension, typically in micrometers. When divided by the lens or mirror focal length, this gives the angular size of the PSF, typically expressed in arc-seconds when specifying astronomical optical system performance.

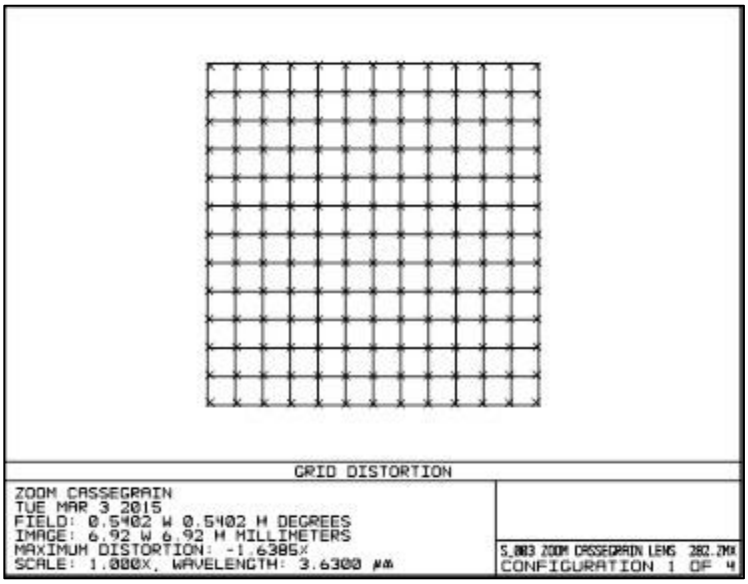


Fig.(6) Grid distortion[12]

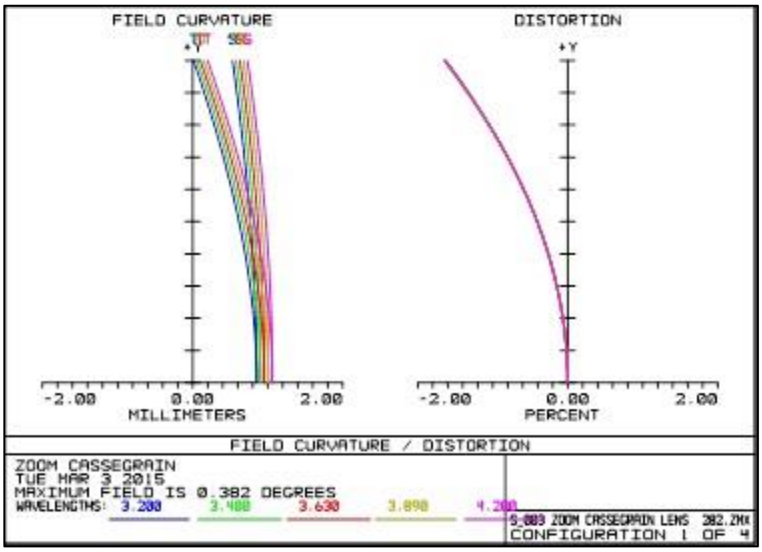


Fig. (7) Field of curvature and distortion[12]

From fig.(6) The grid distortion sees that the maximum distortion (-1.6385%) means that this objective lens has very little distortion with the wave length (3.6300µm) in the fig. (7).and from the Field of curvature and distortion see that the maximum Field is 0.382 deg. means that this objective lens has very little distortion with the wave length(3.200, 3.400, 3.630, 3.890, and 4.200) µm.

IV. CONCLUSION

From above results, we conclude that our telescope can have less aberration when changing the main structure parameters such as thickness, radius and the type of materials made from them. It is observed that there are no coma aberrations seen and the best result is obtained when the angle w=0°. One of the improvements in the design method is that proper scaling can be done in future. This will greatly help in minimizing the spherical aberrations, which still are visible in the present design.This telescope operates in the infrared because infrared photons have lower energies than those of visible light, and Infrared telescopes can detect surrounding too cool environments and while in visible light cannot, such as planets, some nebulae, and brown dwarf stars. Also, infrared radiation has longer wavelengths than visible light, which means it can pass through astronomical gas and dust without scattering. Thus, objects and areas obscured from view in the visible spectrum, including the center of the Milky Way, can be observed in the infrared. These telescopes are gaining popularity and can be completely computer-controlled, giving it what‘s called "GO TO" capability to any object in the sky. One of the improvements in the design method is that proper scaling can be done in future. This will greatly help in minimizing the spherical aberrations, which still are visible in the present design.

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