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Study the effect of the Aperture And Field Of View on Cassegrain Telescopes

دراسة تأثير فتحة الإدخال ومجال الرؤيا على التلسكوب الكاسكريني

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بحـــــث مستـــــل

Abstract:-

In this research study the effect of Aperture and Field Of View on some of the parameters that control the visual quality of the image formed by Cassegrain telescope for the purpose of evaluate the performance of this telescope that study (RMS) Root Mean Square.

The form of the distribution of the rays Encircled Energy (Enc) and A spherical Aberration is one of the most important factors affecting the composition of the image in the telescope and by which they can evaluate the work of the telescope. I have been studying these parameters through the use of program Zemax where the results showed that an increase in Aperture lead to increased A spherical Aberration in the image or visual system also leads at the same time to increase the area of the bright spot (RMS).

The Encircled Energy increase less Aperture System spherical and non-spherical system increases and this evidence quality optical design for the case study of this topic telescope Cassegrain, but the spherical Aberration and Encircled Energy Remains a constant with Field Of View As for the Root Mean Square increase.

الخلاصة:-

تم في هذا البحث دراسة تأثير فتحة الإدخال (Aperture)على بعض المعلمات البصرية التي تتحكم بجودة الصورة المتكونة بواسطة التلسكوب الكاسكريني لغرض تقيم أداء هذا التلسكوب إن دراسة مساحة البقعة المضيئة(RMS) (Root Mean Square) وشكل توزيع الأشعة فيها وكمية الطاقة المتجمعة (Enc) (Encircled Energy) والزيغ الكروي (spherical Aberration) تعتبر من أهم العوامل المؤثرة على تكوين الصورة في إي تلسكوب والتي من خلالها يمكن تقيم عمل التلسكوب ولقد تم دراسة هذه المعلمات من خلال استخدام برنامج Zemaxحيث أظهرت النتائج أن زيادة فتحة الإدخال يؤدي إلى زيادة الزيغ الكروي في الصورة (أو المنظومة البصرية)، كذلك يؤدي في نفس الوقت إلى زيادة مساحة البقعة المضيئة (RMS)، أما الطاقة المتجمعة فإنها تقل بزيادة فتحة الإدخال للمركبة اللاكروية وتزداد للمركبات الكروية وهذا دليل جودة التصميم البصري لهذه الحالة المدروسة للتلسكوب الكاسكريني. ولكن الزيغ الكروي والطاقة المتجمعة تبقى ثابتة مع تغير مجال الرؤيا اما بالنسبة لمساحة البقعة المضيئة تزداد مع زيادة مجال الرؤيا.

Introduction:

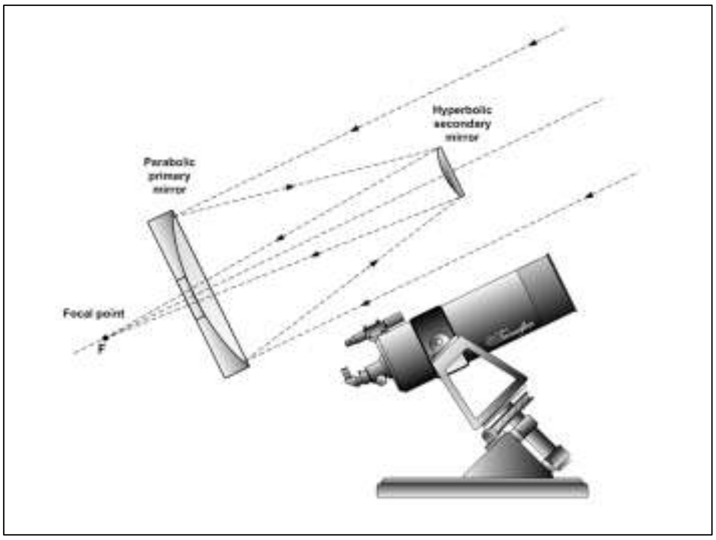
The Cassegrain has a parabolic primary mirror, and a hyperbolic secondary mirror that reflects the light back down through a hole in the primary. Folding the optics makes this a compact design. On smaller telescopes, and camera lenses, the secondary is often mounted on an optically flat, optically clear glass plate that closes the telescope tube. This support eliminates the "star-shaped" diffraction effects caused by a straight-vaned support spider. The closed tube stays clean, and the primary is protected, at the cost of some loss of light-gathering power.

It makes use of the special properties of parabolic and hyperbolic reflectors. A concave parabolic reflector will reflect all incoming light rays parallel to its axis of symmetry to a single point, the focus. A convex hyperbolic reflector has two foci and will reflect all light rays directed at one of its two foci towards its other focus. The mirrors in this type of telescope are designed and positioned so that they share one focus and so that the second focus of the hyperbolic mirror will be at the same point at which the image is to be observed, usually just outside the eyepiece. The parabolic mirror reflects parallel light rays entering the telescope to its focus, which is also the focus of the hyperbolic mirror. The hyperbolic mirror then reflects those light rays to its other focus, where the image is observed [1].

The equation of the telescope:- [2]

$$p=(F+b)/(X+1),\ \ p'=pX,\ B=p'-b,\ \ c=Dp/F+Bi/FX,\ i=X(cF-Dp)/B$$

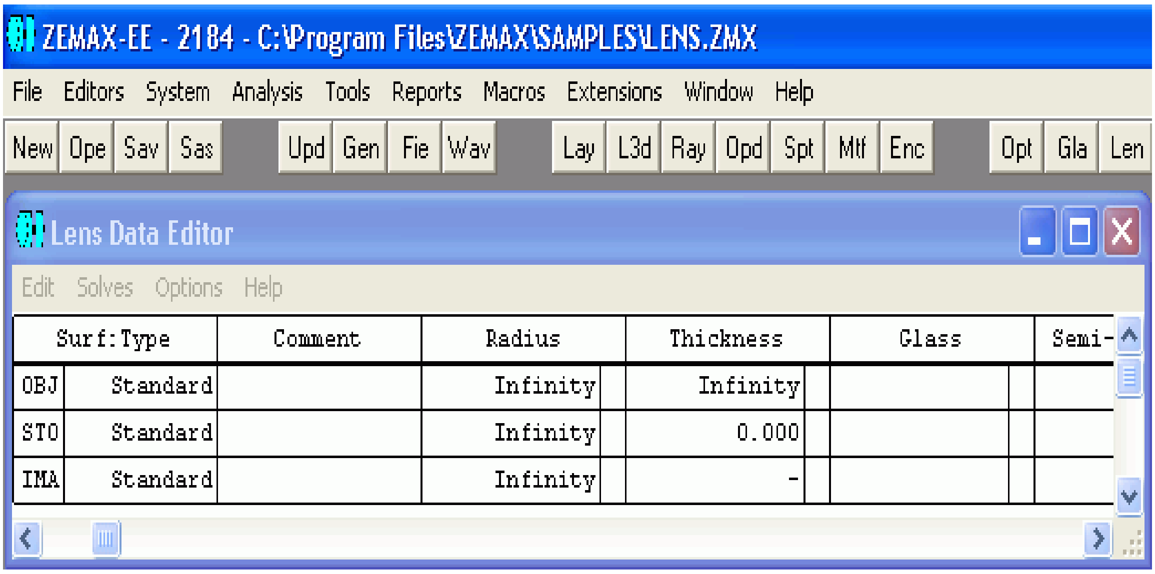
Where: p= primary focus intercept point, p' = secondary to Cassegrain focus, F= primary focal length, X= secondary magnification, b= back focus, B= mirror separation, c = secondary clear aperture, i = final image size, D = primary diameter.



Figure(1) Cassegrain Telescopes

Optical system:-

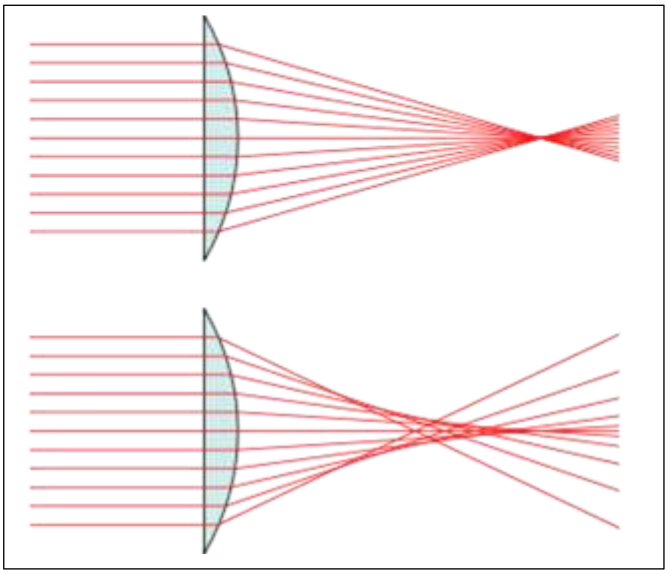
Parameters used Both of the spherical Aberration, Root Mean Square (RMS) and Encircled Energy Study has been affected by these parameters through change Aperture and Field Of View, using an optical design (ZEMAX).



Figure(2) The list shows the Zemax main

1. Spherical aberration:

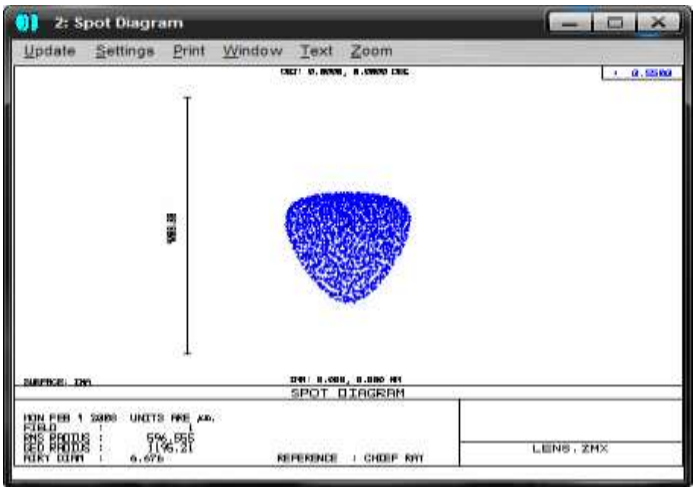
Is an optical effect observed in an optical device (lens, mirror, etc.) that occurs due to the increased refraction of light rays when they strike a lens or a reflection of light rays when they strike a mirror near its edge, in comparison with those that strike nearer the center. It signifies a deviation of the device from the norm, i.e., it results in an imperfection of the produced image [3].



Figure(3) Spherical aberration

2. Root Mean Square:

Is the distance between the radiation source and a point and give a rough idea of the spread of rays because it depends on the shape of the beam[4].

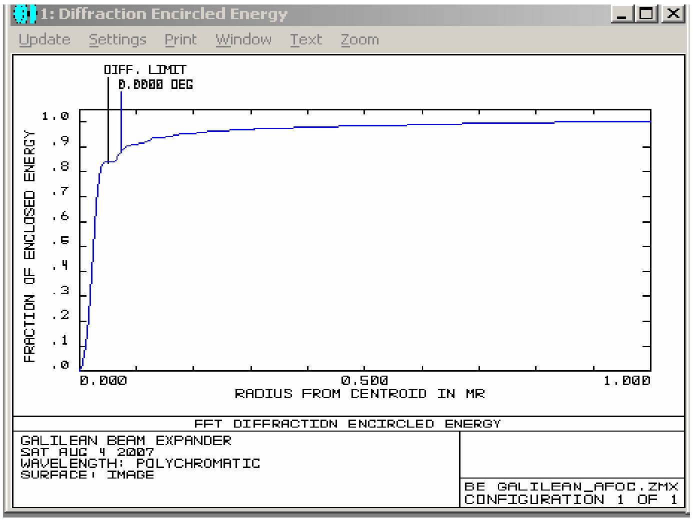


Figure(4) Spot Size

3. Encircled Energy:

Refers to a measure of concentration of energy in an optical image, or projected laser at a given range. If a single star is brought to its sharpest focus by a lens giving the smallest image possible with that given lens (called a point spread function or PSF), calculation of the encircled energy of the resulting image gives the distribution of energy in that PSF, Encircled energy is also used to quantify the spreading of a laser beam at a given distance.

All laser beams spread due to the necessarily limited aperture of the optical system projecting the beam. As in star image PSF's, the linear spreading of the beam expressed as encircled energy is divided by the projection distance to give the angular spreading [5].



Figure(5) Encircled Energy

4. Aperture:-

In optics, an aperture is a hole or an opening through which light travels. More specifically, the aperture of an optical system is the opening that determines the cone angle of a bundle of rays that come to a focus in the image plane. The aperture determines how collimated the admitted rays are, which is of great importance for the appearance at the image plane.[2] If an aperture is narrow, then highly collimated rays are admitted, resulting in a sharp focus at the image plane. If an aperture is wide, then uncollimated rays are admitted, resulting in a sharp focus only for rays with a certain focal length. This means that a wide aperture results in an image that is sharp around what the lens is focusing on and blurred otherwise. The aperture also determines how many of the incoming rays are actually admitted and thus how much light reaches the image plane (the narrower the aperture, the darker the image for a given exposure time). In the human eye, the pupil is the aperture [6].

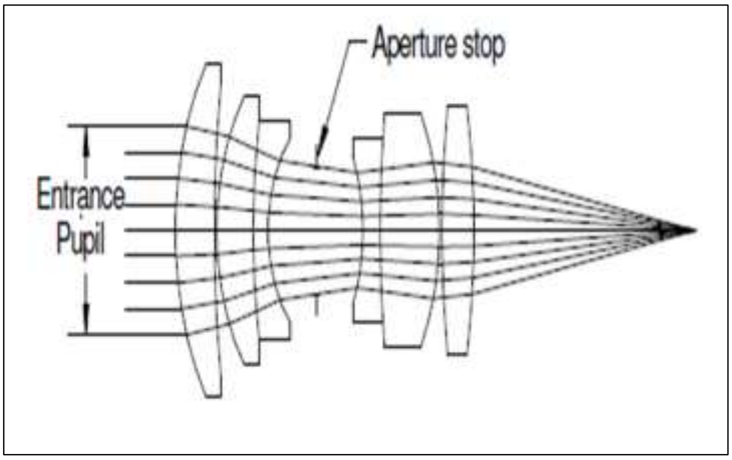
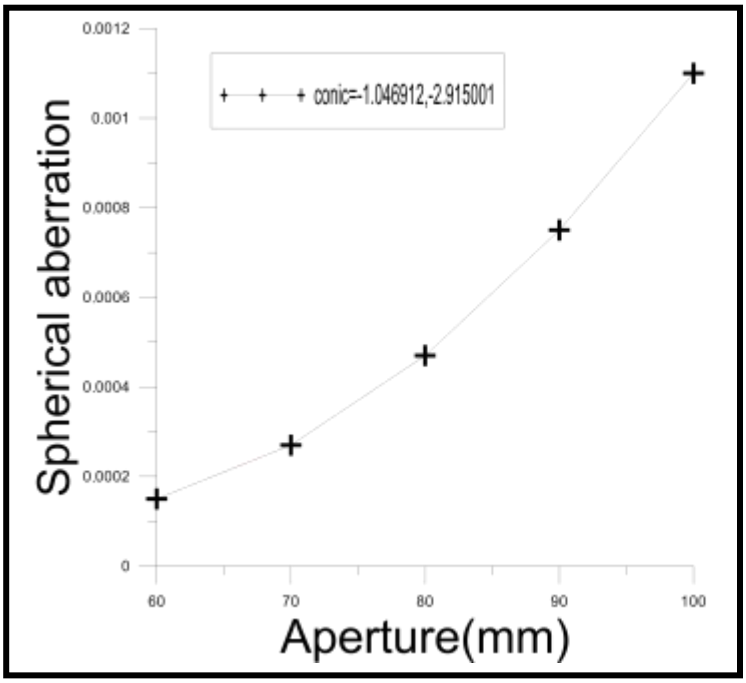


Figure (6) The Aperture **[7]**

(Figure 7) (Table 1), (Figure 8) and table (2) Explain the impact of Aperture on Spherical aberration to A spherical system and spherical system consecutive, Figures have shown that increasing in Aperture lead to increased A spherical Aberration per two system and when comparing the two forms observed in terms of the values of the spherical aberration of each case, we find that the amount of aberration of the ASpherical system lower than that of the spherical system this means that the presence the Spherical mirror blunted the effect the spherical aberration in the optical system. [8], [9].



Figure(7) shows The effect of the aperture on the spherical aberration of the system A spherical.

Table (1) change the aperture with spherical aberration when the field of view= 0, λ=0.55μm, conic=-1.046912,-2.915001

Aperture(mm)	60	70	80	90	100
Spherical aberration	0.00015	0.00027	0.00047	0.00075	0.0011

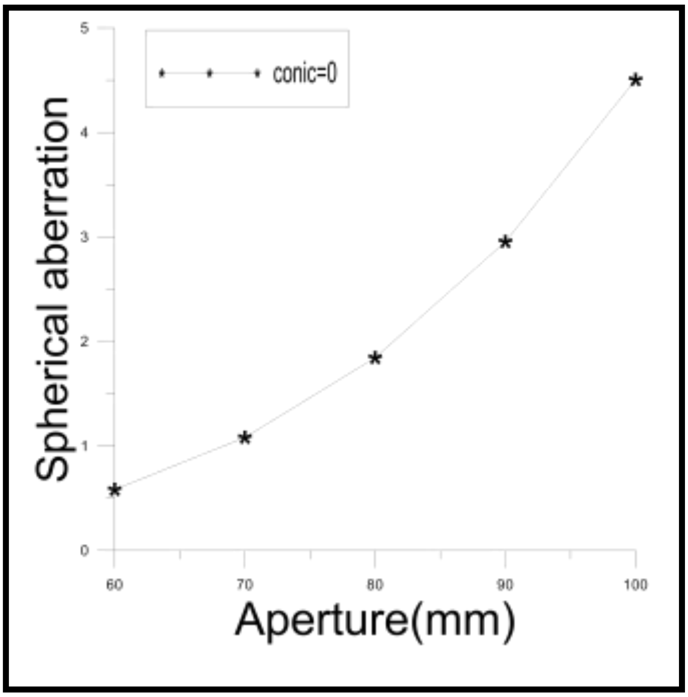


Figure (8) shows The effect of the aperture on the spherical aberration of the system spherical.

Table (2) change the aperture with spherical aberration when the field of view= 0 ،λ=0.55μm،conic=0

Aperture(mm)	60	70	80	90	100
Spherical aberration	0.583	1.0817	1.845	2.955	4.505

We note that the enter optical elements in A Spherical design reduces the effect of increasing the diameter Aperture on the amount of aberration accompanying the optical system and this is what can be the designer of the use of relatively large holes to collect the largest amount of light emitted from the body and thus get a more clear picture.

The effect of Aperture on the spot Size:

Indicate shapes (9) and (10) and tables (3) and (4) the impact of Aperture on an area of the spot (RMS) for the design of the spherical design and A spherical respectively, and the two forms is clear that the space bright spot (RMS) increases when changing the value of Aperture from (60-100) is illustrated by the shapes (11) and (12), and through the tables shows that the RMS values decreased from 74.650 to 0.611 to the design of the spherical design A spherical this result A spherical enter form on the surfaces of lenses (2 and 3). As the vehicles A spherical reduce the spot size by addressing the spherical aberration. [10] , [11]

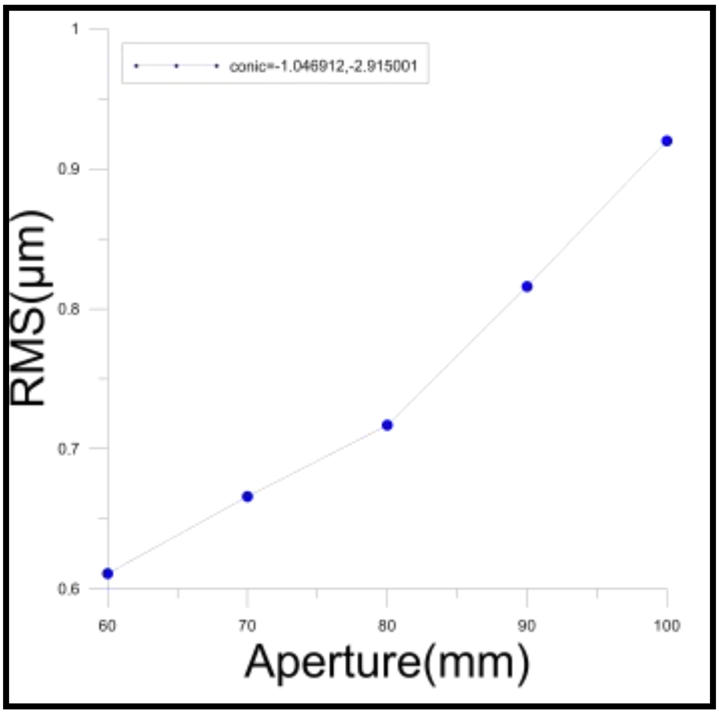
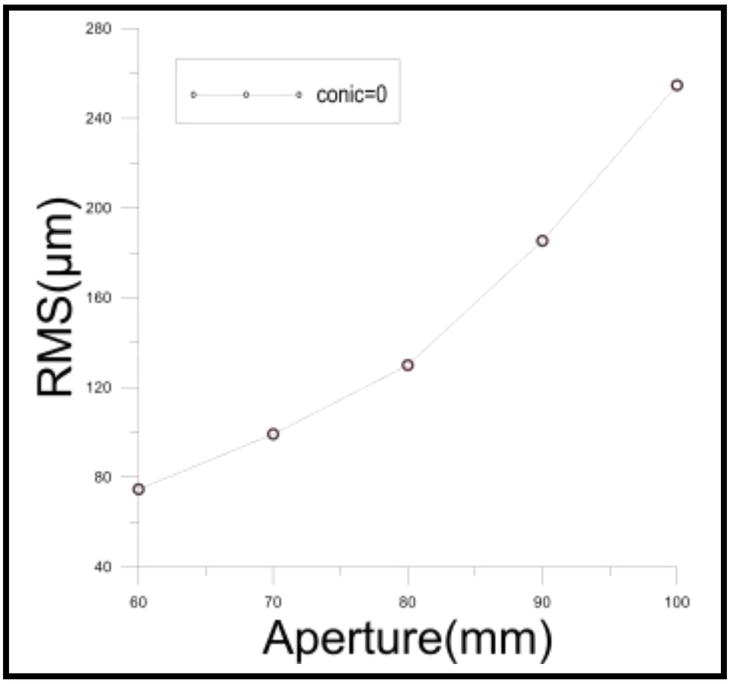


Figure (9) shows The effect of the aperture the spot size for the system to A spherical.

Table (3) change the aperture with spot size when the field of view= 0 ،mμ λ=0.55، conic=-1.046912,-2.915001

Aperture(mm)	60	70	80	90	100
RMS(μm)	0.611	0.666	0.717	0.816	0.920

Shown in Figure (10) that the increase in Aperture increases the size of the spot light and the output from entering the orders aberration to the spot and thus increase its size and as the use of elements A Spherical reduces Spherical aberration Since the rays fall angle zero with the optical axis (paraxial approximation), so the use of A Spherical surfaces reduces the size of the bright spot.



Figure(10)shows The effect of the aperture the spot size for the system to spherical.

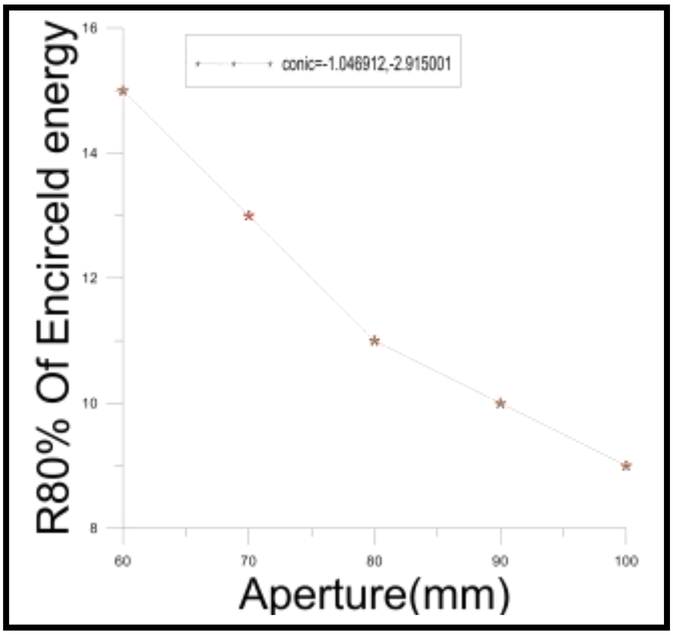
Table (4) change the aperture with spot size when the field of view= 0 ، λ=0.55µm، conic=0

Aperture(mm)	60	70	80	90	100
RMS(µm)	74.650	99.218	129.949	185.375	254.714

The effect of the Aperture on the Encircled Energy: -

That figure (11) shows the amount of Encircled Energy in the level of the picture and note from the table (5) The amount of Encircled Energy least to increase the Aperture, and through the curve of energy that we can infer the quality of non-quality optical design, the more the tendency curved small Encircled Energy what can be the greatest, where the note of confusion (15) the radius when the value of the Encircled Energy least 80% of the impact of the Aperture of the A spherical design .

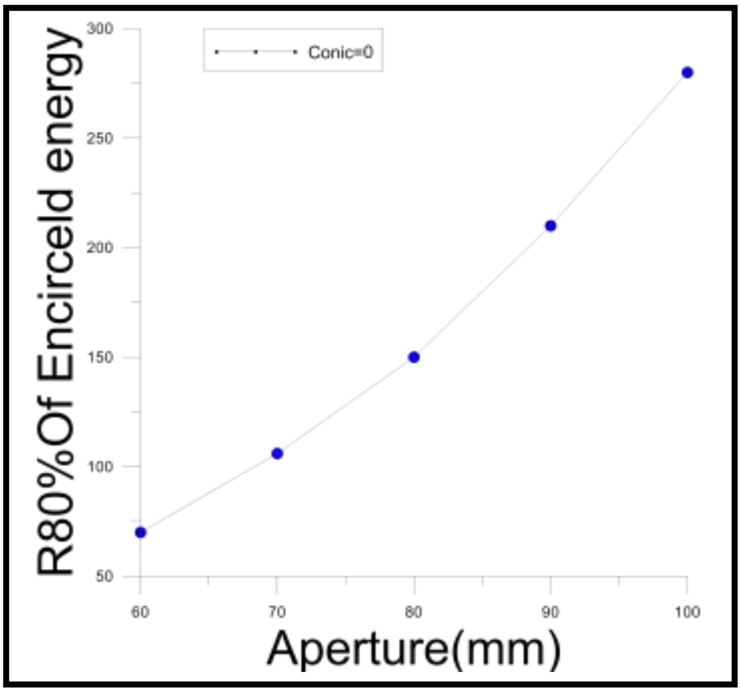
Either to the system as spherical as seen from Figure (12) and table (6) increase the amount of Encircled Energy with increasing Aperture, due to the value of the radius when the Encircled Energy 80% increase the influence of the hole thus the energy gather in larger point, and this means an area of the spot light biggest (RMS) and by selected area in the search. [13], [12]



Figure(11)shows The effect of the aperture the Encircled Energy for the system to A spherical.

Table (5) change the aperture with Encircled Energy when the field of view= 0 ، λ=0.55µm، conic=-1.046912,-2.915001

Aperture(mm)	60	70	80	90	100
Encircled energy	15	13	11	10	9



Figure(12)shows The effect of the aperture for the Encircled Energy for the system to spherical.

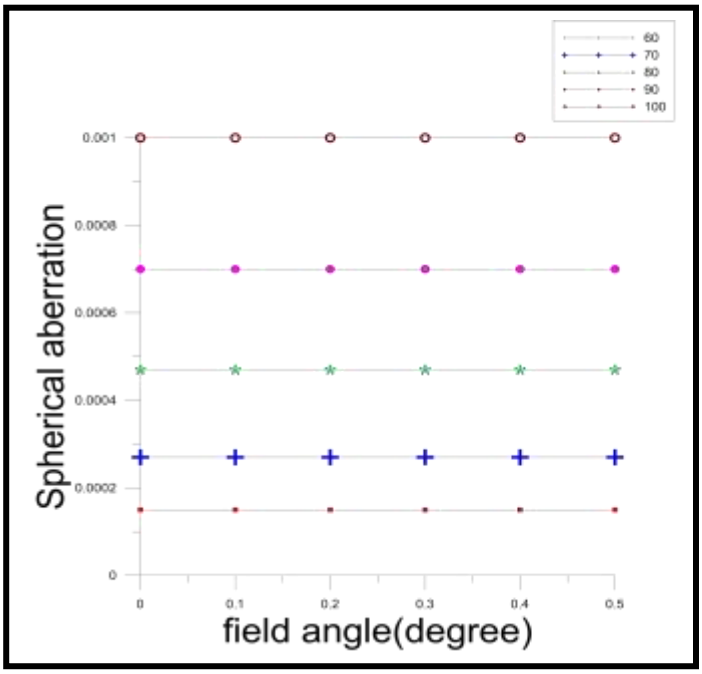
Table (6) change the aperture with Encircled Energy when the field of view= 0 ،λ=0.55μm، conic=0

Aperture(mm)	60	70	80	90	100
Encircled energy	70	106	150	210	280

The effect of the field of view:

The effect of the field of view on the spherical aberration:

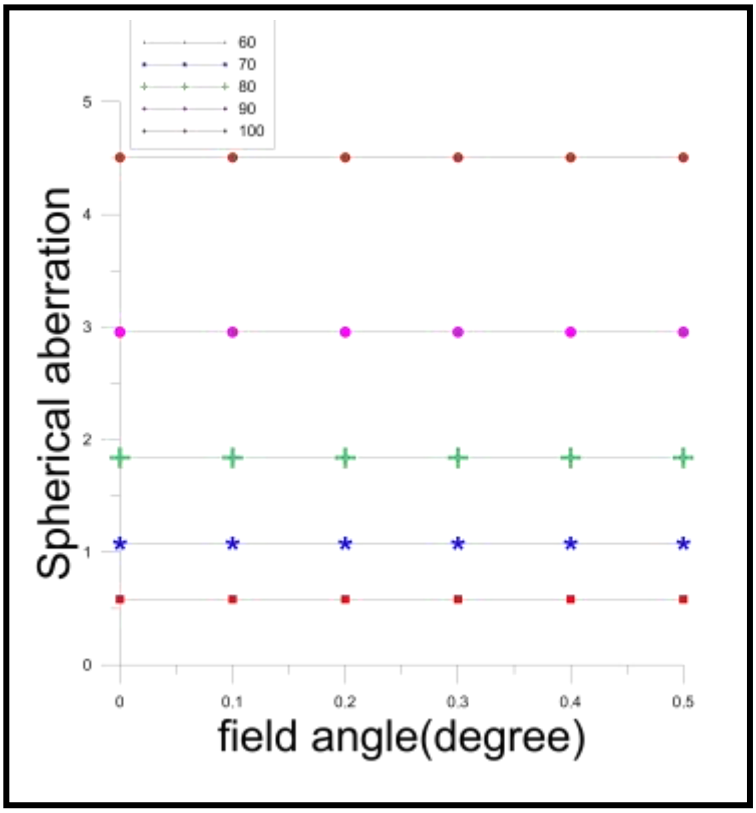
Note of Figures (13) and (14) Tables (7) and (8) The spherical aberration remain constant with the change of the field of view (0-0.5) degree The reason this is to use a parabolic mirror these mirror to reduce spherical aberration for each of the two systems A spherical and spherical respectively.



Figure(13) shows The effect of the field of view on the spherical aberration of the system A spherical.

Table (7) change the aperture with spherical aberration when =0.55µmλ, conic=-1.04619,-2.915001,

Aperture / Field angle (Degree)	60	70	80	90	100
0	0.00015	0.00027	0.00047	0.0007	0.001
0.1	0.00015	0.00027	0.00047	0.0007	0.001
0.2	0.00015	0.00027	0.00047	0.0007	0.001
0.3	0.00015	0.00027	0.00047	0.0007	0.001
0.4	0.00015	0.00027	0.00047	0.0007	0.001
0.5	0.00015	0.00027	0.00047	0.0007	0.001

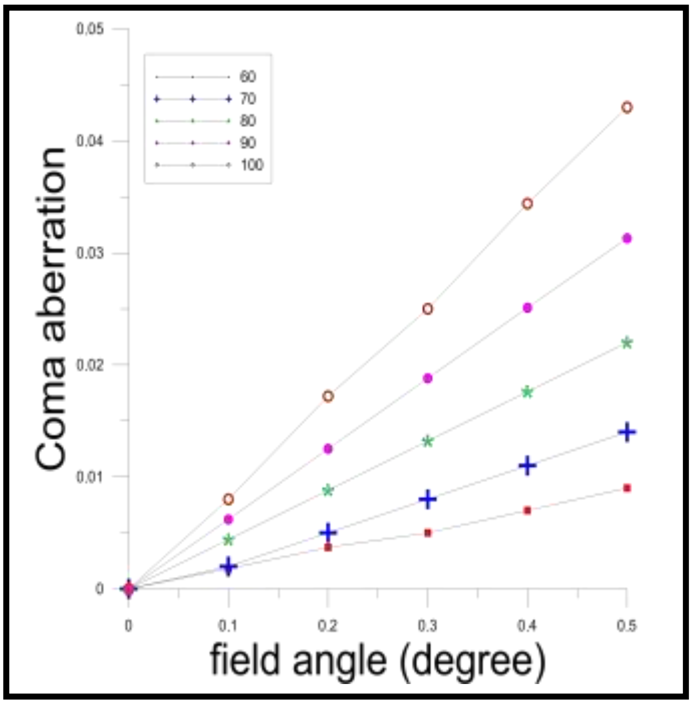


Figure(14) shows The effect of the field of view on the spherical aberration of the system spherical.

Table (8) change the aperture with spherical aberration when mμ=0.55 λconic=0

Aperture / Field angle (Degree)	60	70	80	90	100
0	0.583	1.08	1.84	2.955	4.505
0.1	0.583	1.08	1.84	2.955	4.505
0.2	0.583	1.08	1.84	2.955	4.505
0.3	0.583	1.08	1.84	2.955	4.505
0.4	0.583	1.08	1.84	2.955	4.505
0.5	0.583	1.08	1.84	2.955	4.505

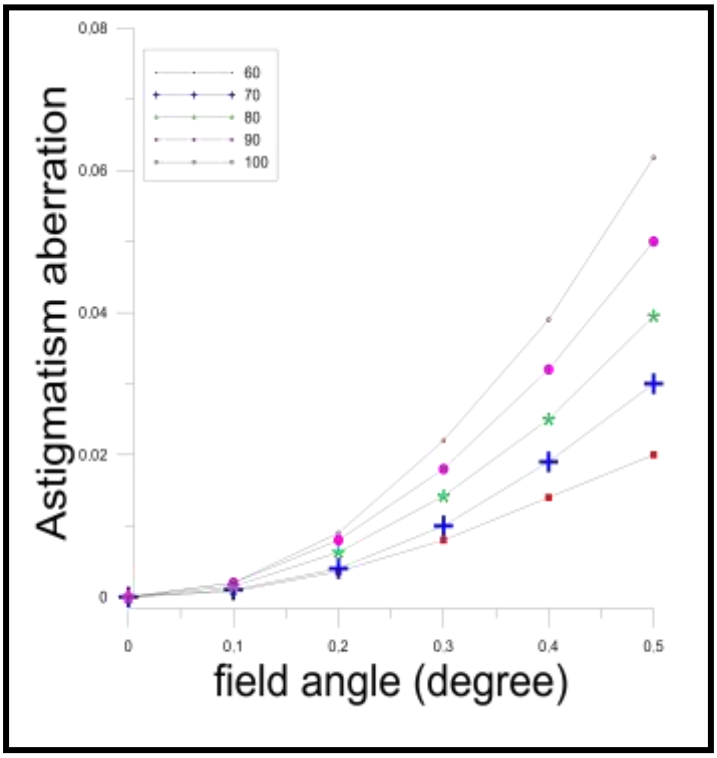
We note through tables (9) to (16), but the Figures (15) to (22) for each of the system and the system A spherical and spherical aberration is the emergence of senior ranks increases with increasing field and the reason for this is that in the work area aberration A spherical non-symmetrical (OFF-axis) this is clear evidence of the quality of the design.[14]



Figure(15) shows The effect of the field of view on the Coma aberration of the system A spherical.

Table (9) change the aperture with Coma aberration when =0.55μm λ, conic=-1.04619,-2.915001,

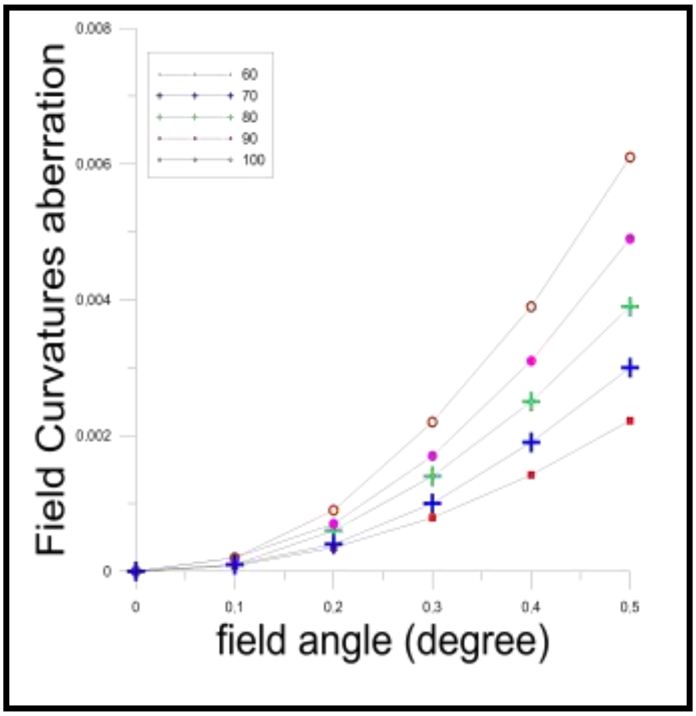
Aperture(mm) / Field angle (Degree)	60	70	80	90	100
0	0	0	0	0	0
0.1	0.0018	0.002	0.0044	0.0062	0.008
0.2	0.0037	0.005	0.008	0.0125	0.017
0.3	0.065	0.008	0.0132	0.0188	0.025
0.4	0.007	0.011	0.0176	0.0251	0.034
0.5	0.009	0.014	0.0220	0.0313	0.043



Figure(16) shows The effect of the field of view on the Astigmatism aberration of the system A spherical.

Table (10) change the aperture with Astigmatism aberration when mμ=0.55 λconic=-1.04619,-2.915001,

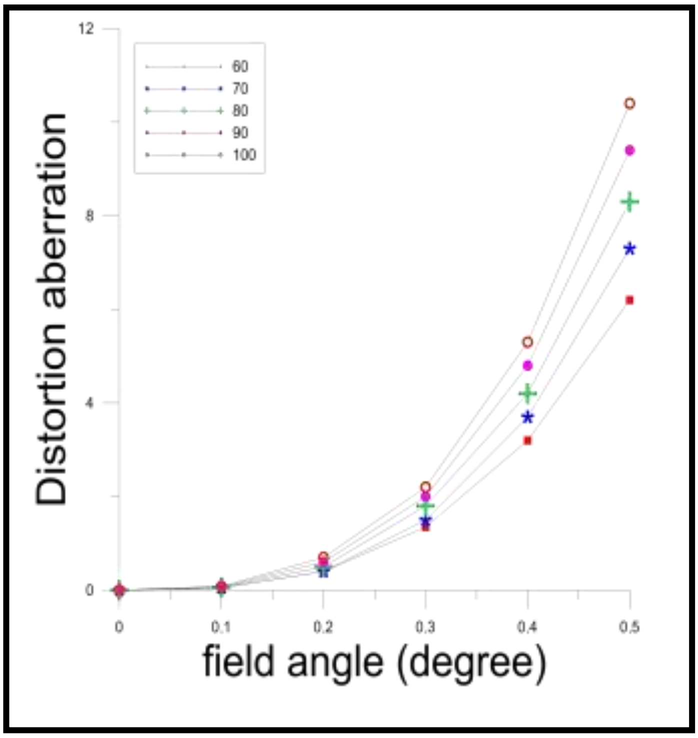
Aperture(mm) / Field angle (Degree)	60	70	80	90	100
0	0	0	0	0	0
0.1	0.0008	0.001	0.0015	0.002	0.002
0.2	0.0036	0.004	0.0063	0.008	0.009
0.3	0.008	0.01	0.0142	0.018	0.022
0.4	0.014	0.019	0.0250	0.032	0.039
0.5	0.02	0.030	0.0395	0.050	0.061



Figure(17) shows The effect of the field of view on the Field Curvatures aberration of the system A spherical.

Table (11) change the aperture with Field Curvatures aberration when λ=0.55 λmμ, conic=-1.04619,-2.915001

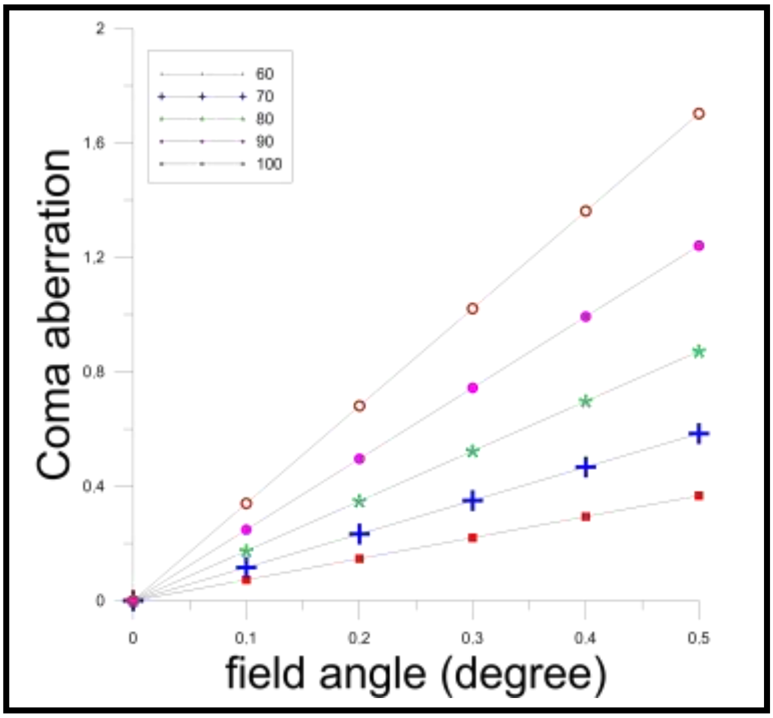
Aperture(mm) / Field angle (Degree)	60	70	80	90	100
0	0	0	0	0	0
0.1	0.00008	0.0001	0.00015	0.0002	0.0002
0.2	0.00035	0.0004	0.00063	0.0007	0.0009
0.3	0.00079	0.0011	0.00142	0.0017	0.0022
0.4	0.00142	0.0019	0.00025	0.0031	0.0039
0.5	0.00222	0.0030	0.00039	0.0049	0.0061



Figure(18) shows The effect of the field of view on Distortion aberration of the system A spherical.

Table (12) change the aperture with Field Curvatures aberration when mμ=0.55 λconic=-1.04619,-2.915001,

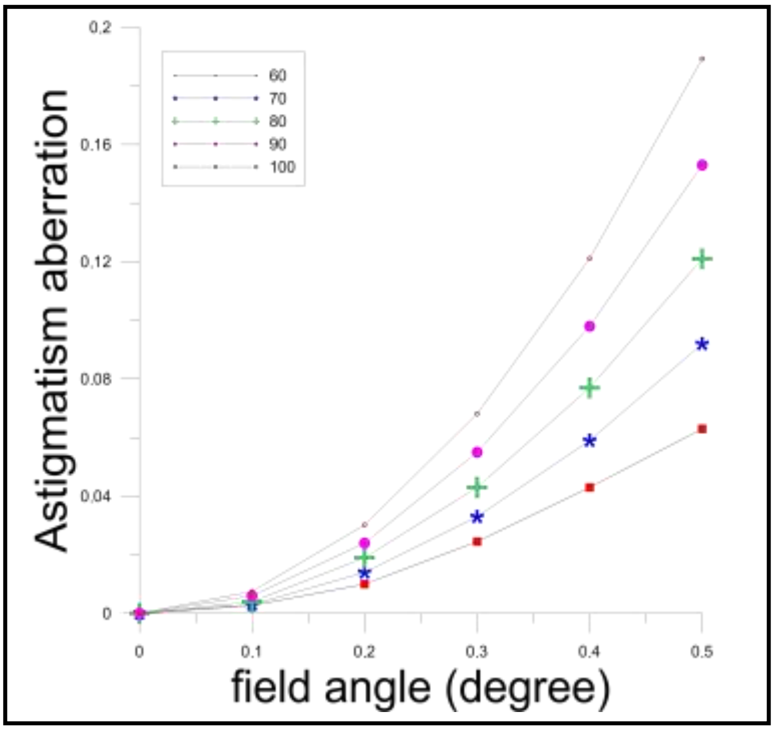
Aperture(mm) / Field angle (Degree)	60	70	80	90	100
0	0	0	0	0	0
0.1	0.05	0.05	0.06	0.07	0.08
0.2	0.4	0.4	0.5	0.6	0.07
0.3	1.3	1.5	1.8	2.0	2.2
0.4	3.2	3.7	4.2	4.818	5.3
0.5	6.2	7.3	8.3	9.4	10.4



Figure(19) shows The effect of the field of view on the Coma aberration of the system spherical.

Table (13) change the aperture with Coma aberration when =0.55µm λ, conic=0

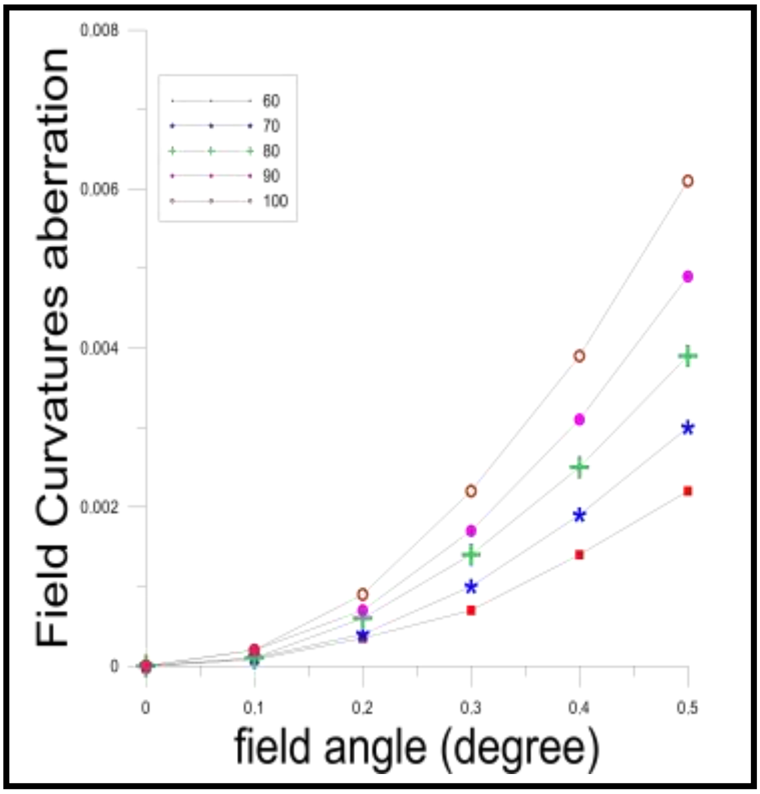
Aperture(mm) / Field angle (Degree)	60	70	80	90	100
0	0	0	0	0	0
0.1	0.073	0.116	0.174	0.248	0.340
0.2	0.147	0.233	0.348	0.496	0.681
0.3	0.220	0.350	0.523	0.744	1.021
0.4	0.294	0.467	0.697	0.993	1.362
0.5	0.367	0.584	0.872	1.241	1.703



Figure(20) shows The effect of the field of view on the Astigmatism aberration of the system spherical.

Table (14) change the aperture with Astigmatism aberration conic=0,λ=when 0.55μm

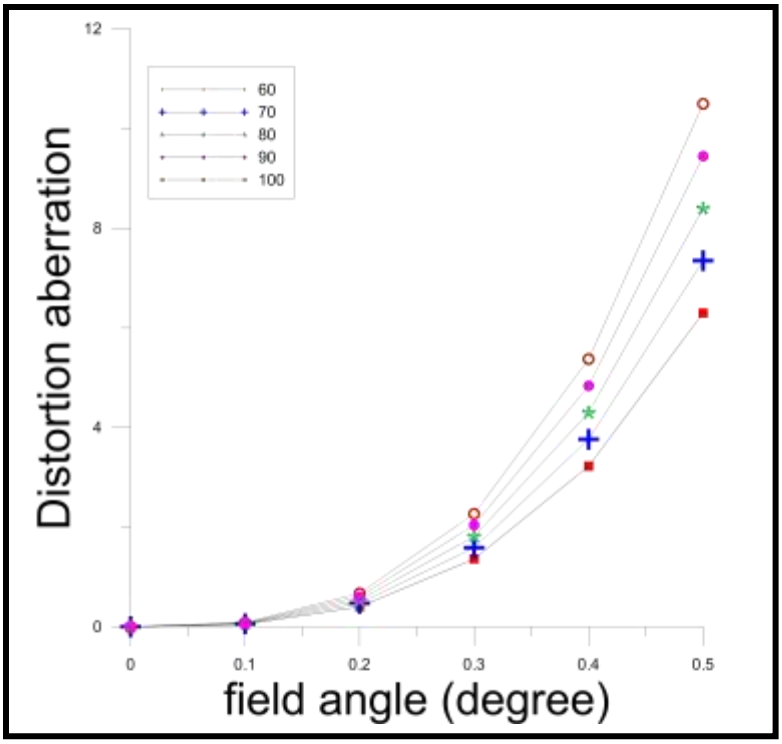
Aperture(mm) / Field angle (Degree)	60	70	80	90	100
0	0	0	0	0	0
0.1	0.0027	0.003	0.004	0.006	0.0075
0.2	0.010	0.014	0.019	0.024	0.0302
0.3	0.0245	0.033	0.043	0.055	0.0681
0.4	0.043	0.059	0.077	0.098	0.1211
0.5	0.063	0.092	0.121	0.153	0.1893



Figure(21) shows The effect of the field of view on the Field Curvatures aberration of the system spherical.

Table (15) change the aperture with Field Curvatures aberration when =0.55μm λconic=0,

Aperture(mm) / Field angle (Degree)	60	70	80	90	100
0	0	0	0	0	0
0.1	0.00008	0.0001	0.0001	0.0002	0.0002
0.2	0.00035	0.0004	0.0006	0.0007	0.0009
0.3	0.0007	0.0010	0.0014	0.0017	0.0022
0.4	0.0014	0.0019	0.0025	0.0031	0.0039
0.5	0.0022	0.0030	0.0039	0.0049	0.0061



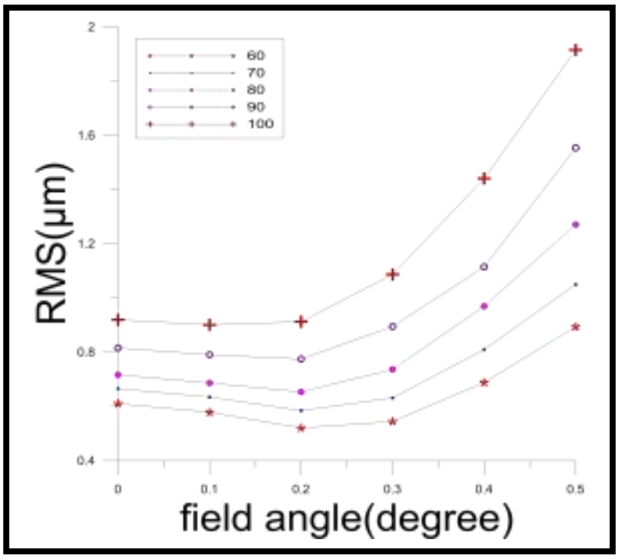
Figure(22) shows The effect of the field of view on Distortion aberration of the system spherical.

Table (16) change the aperture with Field Curvatures aberration when =0.55µm λconic=0,

Aperture(mm) / Field angle (Degree)	60	70	80	90	100
0	0	0	0	0	0
0.1	0.050	0.058	0.067	0.070	0.083
0.2	0.402	0.470	0.537	0.604	0.671
0.3	1.360	1.586	1.813	2.040	2.266
0.4	3.223	3.761	4.298	4.835	5.372
0.5	6.296	7.346	8.395	9.444	10.494

The effect of the field of view on spot size:

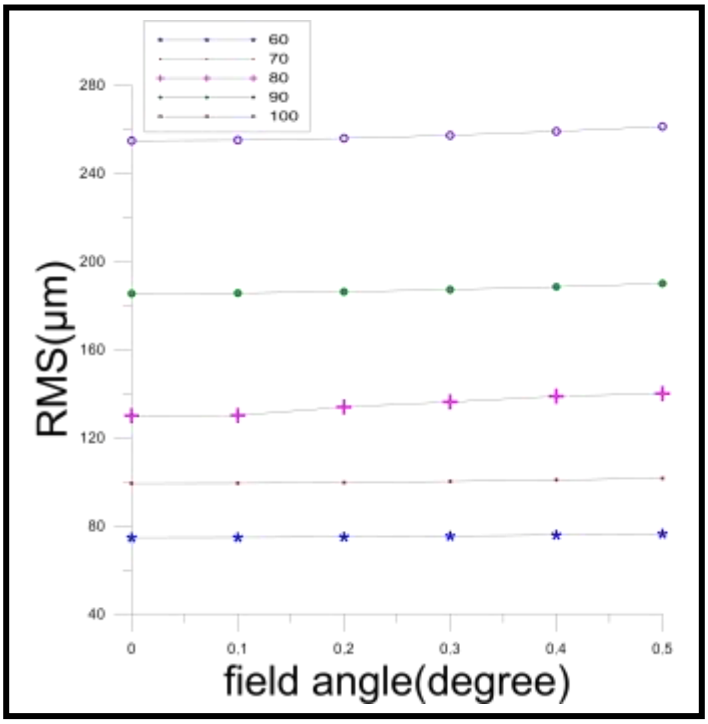
Clear from the shapes (23) - (24) and tables (17) - (18) RMS spot size change with the field of view of the Aperture where we note whenever increased aperture values increased RMS note that the user field defines the area of Qatar input slot for the two systems A spherical and spherical respectively Whenever we wanted to use a large aperture to collect the largest amount of light it must increase the angle of the field and this is evident in the figures (29) - (30).



Figure(23)shows The effect of the Field of view for Spot size the system to A spherical.

Table (17) change field of view with Spot size
λ=0.55μm، conic=-1.046912,-2.915001

Aperture(mm) / Field angle (Degree)	60	70	80	90	100
0	0.611	0.666	0.717	0.816	0.920
0.1	0.579	0.635	0.687	0.791	0.901
0.2	0.521	0.585	0.654	0.775	0.913
0.3	0.545	0.632	0.737	0.895	1.087
0.4	0.689	0.810	0.970	1.115	1.441
0.5	0.894	1.05	1.271	1.554	1.915



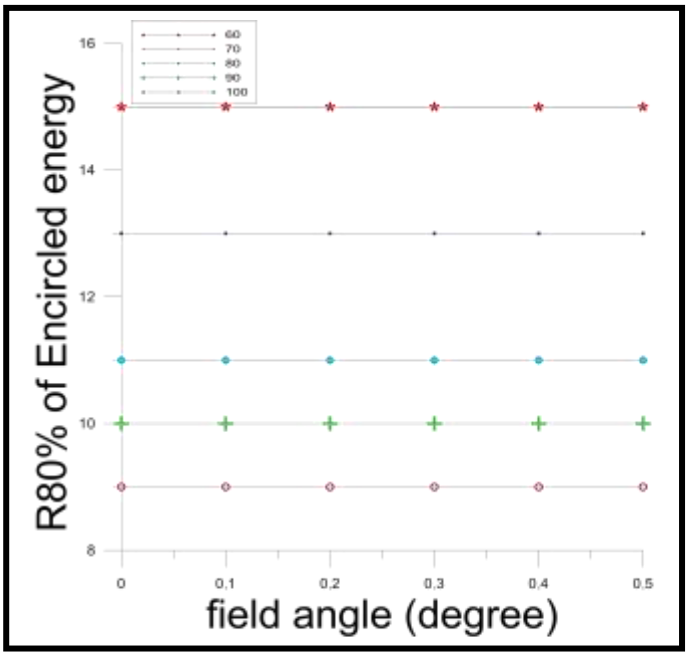
Figure(24) shows The effect of the Field of view for Spot size the system to A spherical.

Table (18) change the Field of view with field of conic=0،λ=view when 0.55µm

Aperture(mm) / Field angle (Degree)	60	70	80	90	100
0	74.65	99.218	129.949	185.375	254.714
0.1	74.736	99.330	130.095	185.581	254.995
0.2	74.984	99.657	133.932	186.186	255.826
0.3	75.370	100.170	136.208	187.157	257.172
0.4	75.852	100.824	138.792	188.441	258.975
0.5	76.382	101.561	139.998	189.963	261.156

The effect of the field of view on the Encircled energy:

That figure (25) and Table (19) shows the amount of Encircled energy in the level of the image where we note that the amount of Encircled energy remains in the case of a constant increase of the field, and shows curved shape Encircled energy on the quality and lack of quality optical design and this is evident through the figures (26) , the more the small curved had the greatest energy as possible.



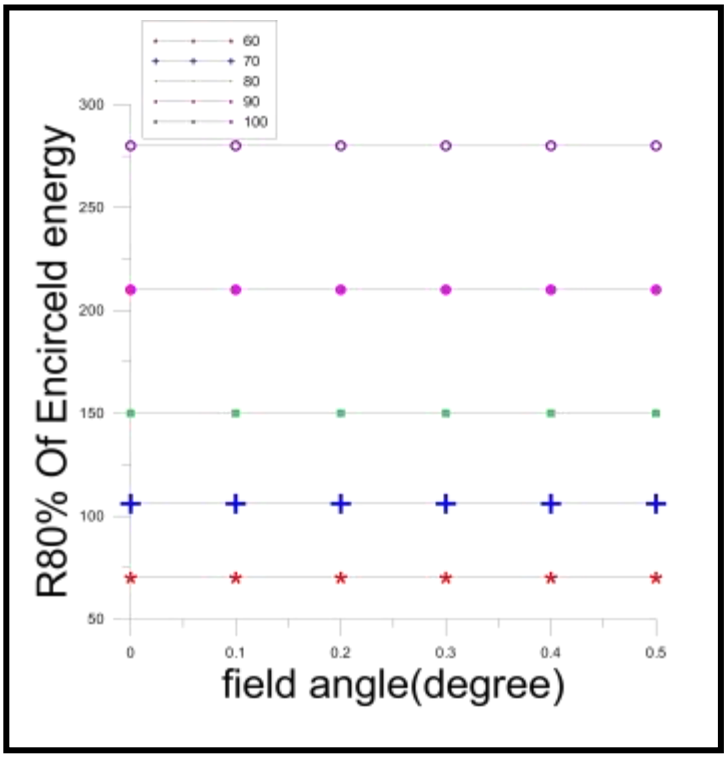
Figure(25)shows The effect of the Field of view for the Encircled Energy for the system to A spherical

Figure(19)shows The effect of the aperture for the Encircled Energy for the system to spherical. 0.55μm،λ= conic=-1.046912,-2.915001

Aperture(mm) / Field angle (Degree)	60	70	80	90	100
0	15	13	11	10	9
0.1	15	13	11	10	9
0.2	15	13	11	10	9
0.3	15	13	11	10	9
0.4	15	13	11	10	9
0.5	15	13	11	10	9

The effect of field of view on the Encircled energy spherical system:

That figure (26) and Table (20) shows the amount of Encircled energy in the level of the image where we note that the amount of Encircled energy remains in the case of a constant increase of the field, and shows curved shape Encircled energy on the quality and lack of quality optical design, the more the small curved had the greatest energy as possible.



Figure(26)shows The effect of the Field of view for the Encircled Energy for the system to spherical

Table (20) change the aperture with Encircled Energy
conic=0 λ=0.55μm

Aperture(mm) / Field angle (Degree)	60	70	80	90	100
0	70	106	150	210	280
0.1	70	106	150	210	280
0.2	70	106	150	210	280
0.3	70	106	150	210	280
0.4	70	106	150	210	280
0.5	70	106	150	210	280

Conclusions:-

1- increasingly spherical aberration to increase the Aperture, it was noted that the use of A spherical systems decreased the influence of the spherical aberration.
2- Spot Size less than the impact of the input slot and note that the entry A spherical systems reduce aberrations generated so it will be less than the value of spot Size.
3- The amount of Encircled Energy less than to increase space slot input to the A spherical system, either for the system spherical is increasingly with increasing the area of Aperture, and because of this is that the value of the radius at 80% of the Encircled Energy increase the influence of the Aperture, because the energy accumulate in larger point means pot size becomes larger.
4- The spherical aberration remains constant with the change of the field of view.
5- The Encircled Energy and Spot Size remains constant to increase in the area and the reason for this is that the impact area will be outside the optical axis OF-axis and this is evidence of the quality of the design.

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