The Effect of Spot Size on the Fractal Optical Modulation

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Abstract

The present paper analyzes the signal emitting from the Reticle during changing the spot size of laser falling on the disk and shows the optimum frequency and the amount of energy window in different patterns of modulator (Reticle).

All results are obtained by establishing a special program named “Disk optical modulator version 3" using the language visual basic 6 ahich contains many parameters. All models of optical modulator consist of twenty sectors, ten sectors are opaque and other ten sectors are transmitted for the laser. The number of sectors depends on several factors as chopping frequency, power transparent and modulation transfer function.

It has been demonstrated by simulations, the optimal value of modulation transfer function is achieved when spot size of laser 0.3 mm and any increasing in spot size lead to decrease in MTF value.

Keywords: Fractal Optical Modulator, Chopping frequency, Spot size, power transparent, the Modulation Transfer Function MTF

Introduction

In any electro- optical tracking systems the optical modulation disk (Reticle) is used as optical filter for background discrimination. The design and movement of the Reticle is to enhance the object and suppress the background. The detection of Reticle is limited to point sources of radiation and to achieve the best efficiency of the disk [1]. In practice, it must not exceed the size of Reticle sector at three times the size of target image. The ideal situation, in fact, occurs when the dimensions of object image is equal to the dimensions sectors Reticle, but the increase in the volume of object image as a result of the approaching electro- optical system is the real motive behind the reduced dimensions of its image in order to start a third remove sections of Reticle, should not exceeding the dimensions spot dimensions of disk sectors [2].

Design of Reticle

There are some factors of spot size affecting on the Reticle design, usually the design of Reticle depends on the following [2, 3, 4]:

1. The nature of work of electro-optical system (negative or positive mode).
2. The type and nature of the objects to be pursued and sources of ambient noise.
3. The dimensions of Reticle.
4. The rotation speed and the number of sectors of Reticle.
5. The requirements of the speed of response of the system.
6. The field of vision to be covered.
7. The nature of the electronic circuits used in signal processing

The dimensional ideal for Reticle design which is based on the progress of the above factors will assume number of assumptions, in electro-optical tracking systems with active mode, the target is illuminated by an external source of lighting, often the source is one type of lasers. Where the principle in such systems, is based on the target (as a reflecting surface diffuse type), thus the source represented as radiation source or lambertian source [4].

Since the proposed range of electro-optical tracking systems is about 5 km therefore has been chosen one solid-state lasers (CW), which is Nd-Yag laser, high energy and wavelength (1.06 micrometers). This wavelength is located within the limits of the optical response detector made of silicon with distinctive characteristics and cheap price [5,6].

Two models has been designed for Reticle; the first design is normal way, so as to compare the results obtained from this model with the results of the second model, which was designed by using Fractal Function,(a new technique) [7,8].

The normal optical modulator is a circular disc which has a radius R, which assumes the number of sector is (twenty sectors), ten sectors are opaque and the other ten sectors are transmitted for the light as shown in Fig (1). One may consider these ten sectors also as opaque for the other regions of electro -magnetic wave spectrum.

By using this concept and IFS (Iterated Function System) kit program [9], we have designed optical modulator as shown in Fig (2). This optical modulator consists of two pattern circles. Each circle is divided into ten transparents and ten opaque sectors (q).

The first pattern, is (inner pattern) designed in a circle with data as shown in Table (1). After conducting the operations of scaling, rotation and iteration (for many times) the obtained pattern is as shown in Fig (2).

The second pattern (outer pattern) is designed in an equilateral triangle with data as shown in Table (2).After (many times) of conducting the operations of scaling, rotation and iteration, the result is as shown in Fig. (2).

Result and Discussion

To get work it has been established a special program named “Disk optical modulator version 3" using the language visual basic 6 which contains many parameters and as shown in Table (3).

When calculating the frequency it has been converted to units (Rev / s), as well as for angular velocity *w,* The Law of frequency is given by [10]:

$$f_r = w/2\pi \qquad \text{..........(1)}$$

$$fc = qfr \qquad \text{............(2)}$$

Where fc chopping Frequency, fr rotation Frequency and q number of sectors.

The basic idea in this research requires expansion the spot size of laser to cover the full Reticle with radius equals to 90 mm and by assuming the power of laser emission from source about P_L= 50 Watt and diameter of spot is r = 3 mm with wavelength $\lambda = 1.06\ \mu m$, and distribution of the power density ϕ in the near field given by [2, 11]:

$$\phi = \frac{P_L}{\pi r^2} \qquad \text{.............(3)}$$

$\phi = 7 \times 10^6\ W/m^2$ for r = 1.5 mm

When extended the spot laser to cover all effective area of reticle become

$\phi = 1965.87\ W/m^2$ for r = 90 mm

The great part of the laser energy will loss as a result of the processes of reflection, absorption, and that will suffer, when passed through the optical components of the transmitter unit, if the transmittance τ of the lens of an expanded package are $\tau_1 = 0.9$ and $\tau_2 = 0.9$, its means lost 20% of the power energy in lens And approximately 80% of the energy falls on a Reticle which have transparent $\tau_3 = 0.9$ for transparent sectors. The power transparent P of each sector is given by the equation [2,11]:

$$p = \phi\, S_n\, \tau_r \qquad \text{.........................(4)}$$

Where $\tau_r = \tau_1 \times \tau_2 \times \tau_3$=0.729 and S_n area of sub sector

The modulation transfer function MTF is calculated for each pattern by calculating the transmittance intensity by using the equation:-

$$MTF = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} \qquad \text{.................................(5)}$$

Where: I_{max}: is transmittance maximum intensity and I_{min} : is oblique minimum intensity .we calculate Imax (the ratio between the spot size and the transmittance area), and I_{min} (the ratio between the spot size and oblique area [12,13]. Then we measure the modulation transfer function MTF by using eq (5).

The results that were obtained based on a number of information assumed as shown in Table (4) and Table (5).

First, we may draw the relationship between the rotation frequency and Chopping frequency with number of sectors, we got the curve shown in Fig(3)

The movement of any section in a circular motion takes approximately 0.0001 seconds (for the disc consists of 10 sections of dark does not allow passage of the power and 10 section window allows passage power) that would lead to cut the signal on an ongoing basis every 0.0001 seconds as shown in Table (6) and Figs (4, 5), which represents the relationship between power transparent and the time, also it shows, that the power transparent is directly proportional with size of sector, consequently the power transparent from fractal Reticle is larger from normal Reticle.

Changing spot size of laser

Theoretically, the best detection occurs when sectors of the disk is determined periodically and the forms and dimensions similar to the form and dimensions of spot, this leads to complete the modulation continues process and reduce the frequency bandwidth occupied by the optical signal to the lowest extent possible, or in other words, reduce the impact of noise to a minimum [2,9,8].

To explain the impact of changing spot size of laser on the fractal modulator frequency, we will change the spot size between 0.3 mm^2 to 0.6 mm^2 from area of sector as shown in Table (7), and then evaluate the best value of MTF depending on Eq.5

In order to unify the values for all models we'll take stairs gradually to cover these Values, depending on the minimum value (0.376 mm^2) and maximum value (0.93mm^2) and between them in the following manner

Spot size in mm^2	0.0003	0.0004	0.0005	0.0006	0.0007	0.0008	0.0009

Tables (8, 9, 10 and 11) shows the results of the fc and modulation transfer function MTF which was obtained as a result of changing the spot size from 0.3 mm^2 to 0.6 mm^2 (as shown in Figure (6)to fig.(13)).

We note that the best value for the MTF was obtained when the size of the section is equal to 0.3 mm2 and any increase in spot size after this value leads to adversely affects on MTF for all models, and this supports what we assumed theoretically for the case of an ideal fit between the spot size and area of the section of the disk.

Conclusion

1 - The outer pattern of fractal Reticle is used to detect the target , which requires that the aperture sizes are larger than the target by three times to achieve the following:

- early detection of distant targets situated within the range of Reticle
- The ability to detect more than one objective, and determine the coordinates of based on its initial size and shape
- Keep the targets under monitoring, especially when approaching where the bigger size
- Give adequate time for the reorientation of the visual system in order to drop in body image exposed on the inner pattern of fractal model by object-oriented lens.

2 - The inner pattern of fractal Reticle is used for the purpose of the lock on the target, and this

requires that the expulsion of the target equals to the dimensions of sectors to achieve the following:

- Complete the modulation continues process and this leads to reduce the impact of noise to a minimum.
- Access to the regular signal and nearly constant frequency.

3. The power transparent is directly proportional with size of sector; consequently the power transparent from fractal Reticle is larger from normal Reticle

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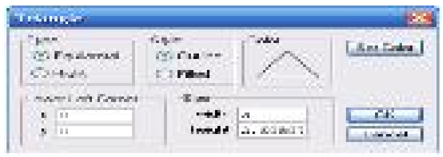
Table (1): The initial shape of the first pattern

Table (2): The initial shape of the second pattern



Table(3) data of Disk optical modulator v.2 Program

Table(4): The results of normal and Reticle disk

State	Normal Reticle	Fractal Reticle	
		Inner Pattern	Outer Pattern
radius	0.09 m	0.03 m	0.09 m
Time	0.002 sec	0.002 sec	0.002 sec
Number of sector	20	20	20
spot size of laser	0.5 mm	0.5mm	0.5 mm
Angle of sector	18 degree	18 degree	18 degree
Circumference	0.5652 m	0.1884 m	0.5652 m
Area of disk	0.025434 m2	0.002826 m2	0.025434 m2
Angular velocity	1744.44 rad/sec	5233.33 rad/sec	1744.44 rad/sec
Rotational frequency	277.77	833.33rad/sec	277.77
Chopping frequency	2777.7 rad/sec	8333.3 rad/sec	2777.7 rad/sec

Table (5): data of sub sector for normal and fractal reticle

State	Normal Reticle	Fractal Reticle	
		Inner Pattern	Outer Pattern
Circumference sub sector	0.02826 m	0.1884 m	0.02826 m
Area of transparent sub sector	0.0012717 m2	0.00001256m2	0.00001558842m2
Area of transparent sector	0.0012717 m2	0.001256m2	0.001558842m2

Table (6) : The power transparent of Reticle disk

No of sector	Time in sec	Power transparent of Normal in Watt	Power transparent of inner fractal in watt	Power transparent of outer fractal in watt
1.	0.0001	0	0	0
2.	0.0002	1.82	1.7999	2.234
3.	0.0003	0	0	0
4.	0.0004	1.82	1.7999	2.234
5.	0.0005	0	0	0
6.	0.0006	1.82	1.7999	2.234
7.	0.0007	0	0	0
8.	0.0008	1.82	1.7999	2.234
9.	0.0009	0	0	0
10.	0.001	1.82	1.7999	2.234
11.	0.0011	0	0	0
12.	0.0012	1.82	1.7999	2.234
13.	0.0013	0	0	0
14.	0.0014	1.82	1.7999	2.234
15.	0.0015	0	0	0
16.	0.0016	1.82	1.7999	2.234
17.	0.0017	0	0	0
18.	0.0018	1.82	1.7999	2.234
19.	0.0019	0	0	0
20.	0.002	1.82	1.7999	2.234

Table(7): data of (0.3 - 0.6)area of sub sector for normal and fractal reticle

Area of transparent sector	$0.0012717m^2$	$0.001256m^2$	$0.001558842m^2$

Normal reticle		Inner pattern		Outer pattern	
State	Spot size	State	Spot size	State	Spot size
0.3	0.000381	0.3	0.000376	0.3	0.00046
0.4	0.000508	0.4	0.0005024	0.4	0.00062
0.5	0.000635	0.5	0.000628	0.5	0.00073
0.6	0.000763	0.6	0.0007536	0.6	0.00093

Table(8):The MTf of Normal and fractal Reticle when Spot size = 0.0003 m

Normal Reticle			Fractal Reticle					
			Inner Pattern			Outer Pattern		
R	Fc	MTF	R	Fc	MTF	R	Fc	MTF
0.009	27777.7	0.096	0.03	8333.33	0.32	0.09	2777.7	0.96
0.018	13888.8	0.192	0.02906	8602.89	0.309	0.08720	2866.97	0.930
0.027	9259.25	0.288	0.026477	9442.15	0.282	0.0794	3148.61	0.846
0.036	6944.44	0.384	0.02287	10931.35	0.243	0.0686	3644.31	0.731
0.045	5555.55	0.48	0.01946	12846.86	0.207	0.05840	4280.82	0.622
0.054	4629.62	0.576	0.018	13888.88	0.192	0.054	4629.62	0.576
0.063	3968.25	0.672	0.01946	12846.86	0.207	0.05840	4280.82	0.622
0.072	3472.22	0.768	0.02287	10931.35	0.243	0.0686	3644.31	0.731
0.081	3086.41	0.864	0.026477	9442.15	0.282	0.0794	3148.61	0.846
0.09	2777.77	0.96	0.02906	8602.89	0.309	0.08720	2866.97	0.930

Table(9):The MTf of Normal and fractal Reticle when Spot size = 0.0004

Normal Reticle			Fractal Reticle					
			Inner Pattern			Outer Pattern		
R	Fc	MTF	R	Fc	MTF	R	Fc	MTF
0.009	27777.77	0.075	0.03	8333.33	0.25	0.09	2777.77	0.75
0.018	13888.88	0.15	0.02906	8602.89	0.242	0.08720	2866.97	0.726
0.027	9259.25	0.225	0.026477	9442.15	0.22	0.0794	3148.61	0.661
0.036	6944.44	0.3	0.02287	10931.35	0.190	0.0686	3644.31	0.571
0.045	5555.55	0.375	0.01946	12846.86	0.162	0.05840	4280.82	0.486
0.054	4629.62	0.45	0.018	13888.88	0.15	0.054	4629.62	0.45
0.063	3968.25	0.525	0.01946	12846.86	0.162	0.05840	4280.82	0.486
0.072	3472.22	0.6	0.02287	10931.35	0.190	0.0686	3644.31	0.571
0.081	3086.41	0.675	0.026477	9442.15	0.22	0.0794	3148.61	0.661
0.09	2777.77	0.75	0.02906	8602.89	0.242	0.08720	2866.97	0.726

Table(10):The MTf of Normal and fractal Reticle when Spot size = 0.0005

Normal Reticle			Fractal Reticle					
			Inner Pattern			Outer Pattern		
R	Fc	MTF	R	Fc	MTF	R	Fc	MTF
0.009	27777.77	0.06	0.03	8333.33	0.2	0.09	2777.77	0.6
0.018	13888.88	0.12	0.02906	8602.89	0.193	0.08720	2866.97	0.581
0.027	9259.25	0.18	0.026477	9442.15	0.176	0.0794	3148.61	0.529
0.036	6944.44	0.24	0.02287	10931.35	0.152	0.0686	3644.31	0.457
0.045	5555.55	0.3	0.01946	12846.86	0.129	0.05840	4280.82	0.389
0.054	4629.62	0.36	0.018	13888.88	0.12	0.054	4629.62	0.36
0.063	3968.25	0.42	0.01946	12846.86	0.129	0.05840	4280.82	0.389
0.072	3472.22	0.48	0.02287	10931.35	0.152	0.0686	3644.31	0.457
0.081	3086.41	0.54	0.026477	9442.15	0.176	0.0794	3148.61	0.529
0.09	2777.77	0.6	0.02906	8602.89	0.193	0.08720	2866.97	0.581

Table(11):The MTf of Normal and fractal Reticle when Spot size = 0.0006

Normal Reticle			Fractal Reticle					
			Inner Pattern			Outer Pattern		
R	**Fc**	**MTF**	**R**	**Fc**	**MTF**	**R**	**Fc**	**MTF**
0.009	27777.77	0.05	0.03	8333.33	0.166	0.09	2777.77	0.5
0.018	13888.88	0.1	0.02906	8602.89	0.161	0.08720	2866.97	0.484
0.027	9259.25	0.15	0.026477	9442.15	0.147	0.0794	3148.61	0.441
0.036	6944.44	0.2	0.02287	10931.35	0.127	0.0686	3644.31	0.381
0.045	5555.55	0.25	0.01946	12846.86	0.108	0.05840	4280.82	0.324
0.054	4629.62	0.3	0.018	13888.88	0.1	0.054	4629.62	0.3
0.063	3968.25	0.35	0.01946	12846.86	0.108	0.05840	4280.82	0.324
0.072	3472.22	0.4	0.02287	10931.35	0.127	0.0686	3644.31	0.381
0.081	3086.41	0.45	0.026477	9442.15	0.147	0.0794	3148.61	0.441
0.09	2777.77	0.5	0.02906	8602.89	0.161	0.08720	2866.97	0.484

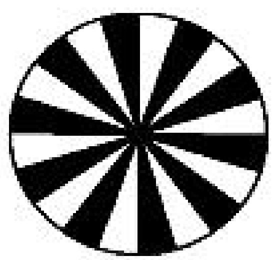


Fig. (1): The Normal optical modulator

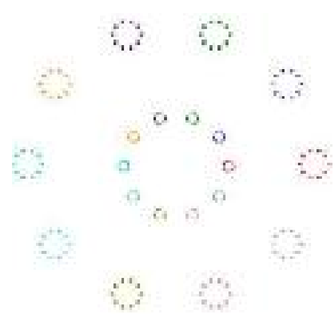


Fig. (2): The fractal optical modulator

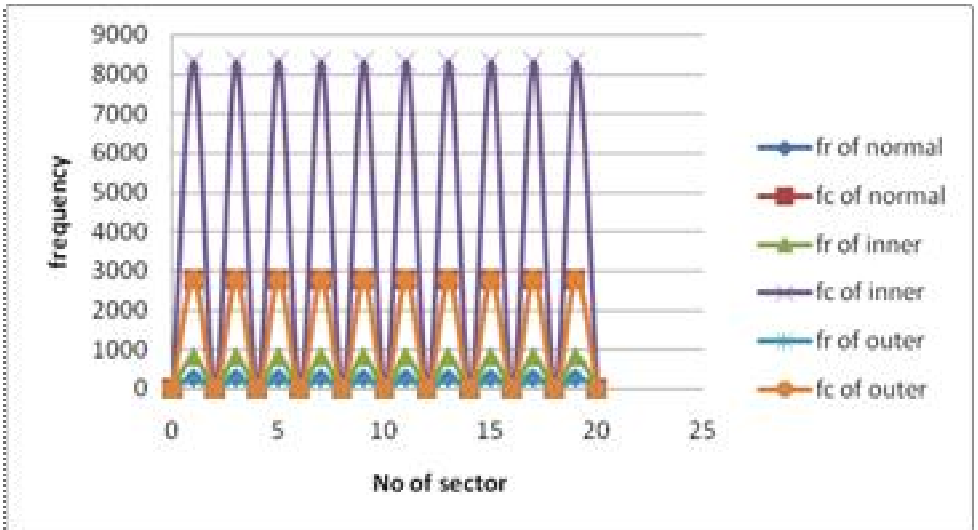


Fig.(3) :The relation between No. of sector versus frequency

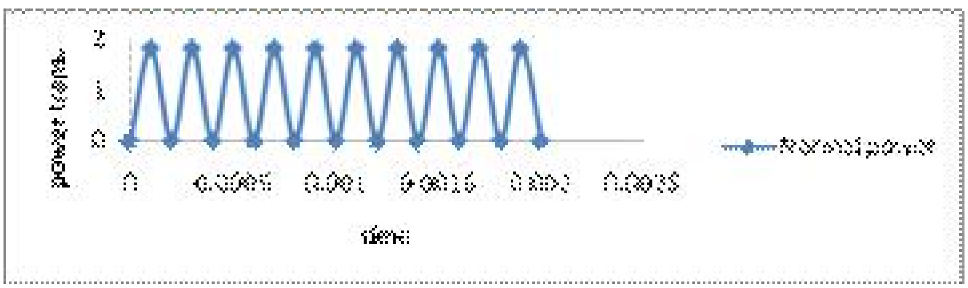


Fig .(4): The relationship between power transparent and the time for Normal Reticle

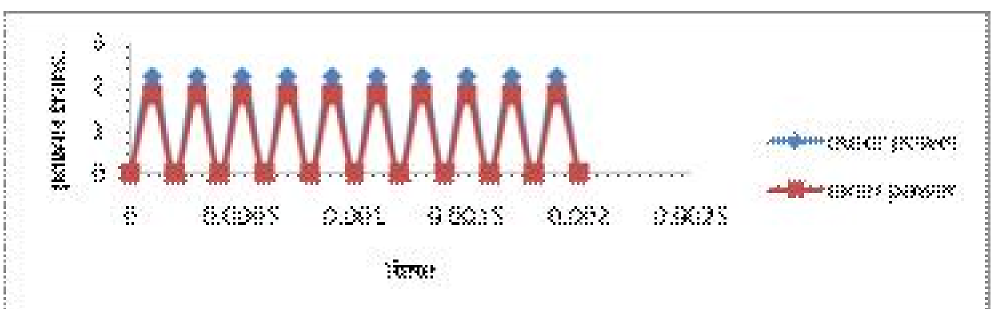


Fig. (5): The relationship between power transparent and the time for fractal Reticle

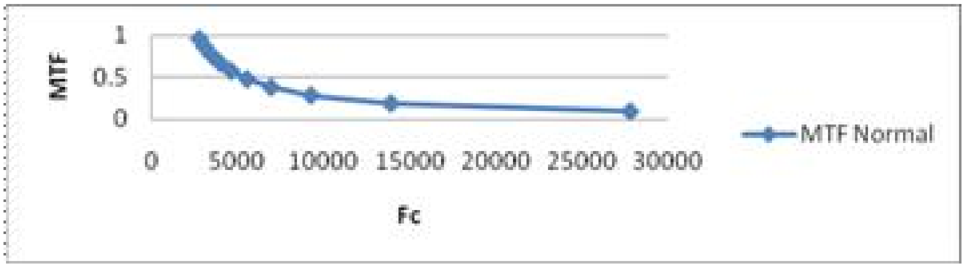


Fig .(6): The MTF versus fc with spot size 0.0003 (Normal Reticle)

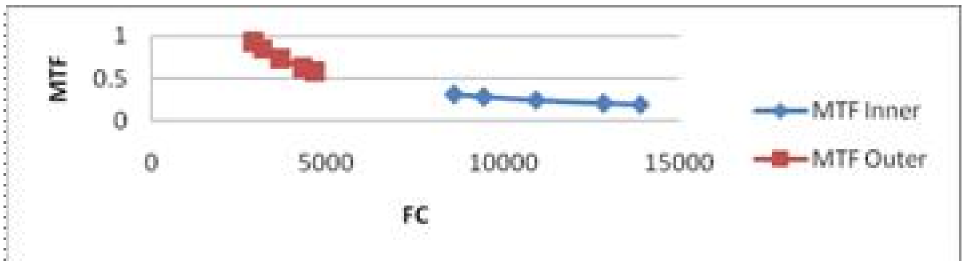


Fig. (7): The MTF versus fc with spot size 0.0003 (fractal Reticle)

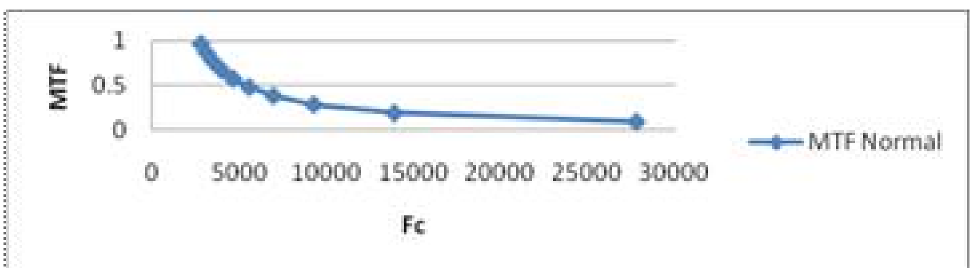


Fig .(8): The MTF versus fc with spot size 0.0004(Normal Reticle)

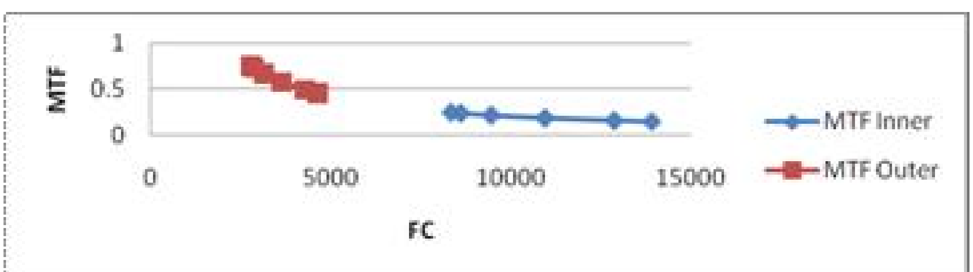


Fig. (9): The MTF versus fc with spot size 0.0004(fractal Reticle)

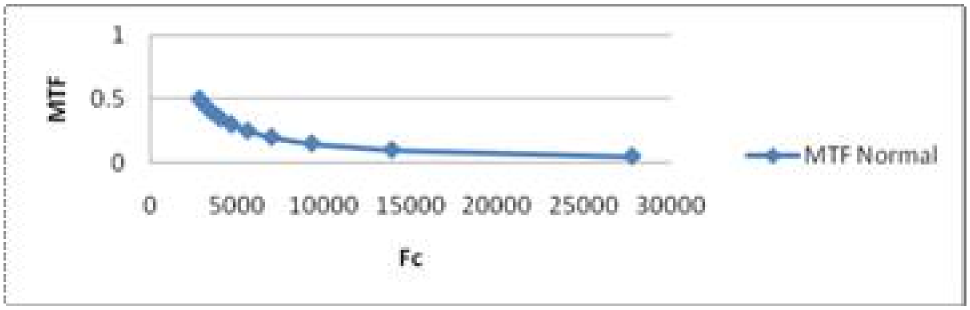


Fig .(10): The MTF versus fc with spot size 0.0005(Normal Reticle)

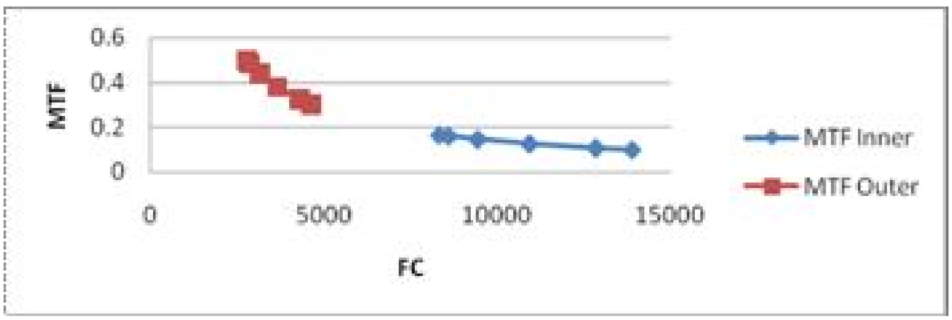


Fig. (11): The MTF versus fc with spot size 0.0005(fractal Reticle)

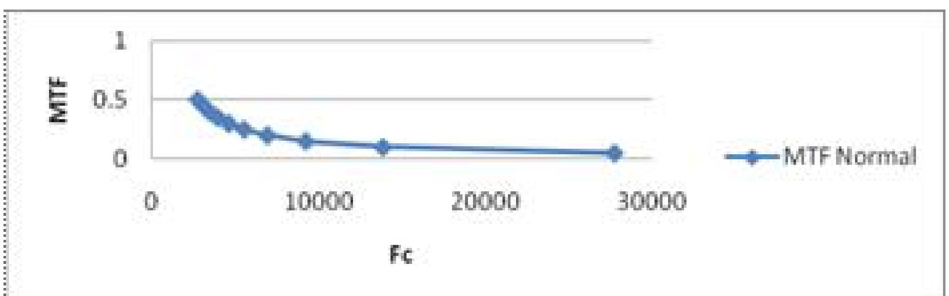


Fig. (12): The MTF versus fc with spot size 0.0006(Normal Reticle)

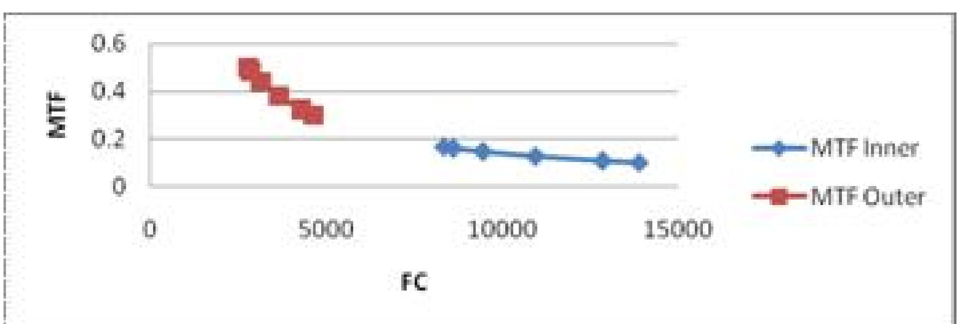


Fig. (13): The MTF versus fc with spot size 0.0006(fractal Reticle)

تأثير حجم البقعة في التضمين البصري الكسوري

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استلم البحث في : 30، تشرين الاول ،2010
قبل البحث في : 27، شباط، 2011

الخلاصة

في هذا البحث حللت الإشارات المنبعثة من قرص التضمين البصري من خلال تغيير حجم بقعة الليزر الساقطة على القرص وحسب افضل تردد من خلال مقدار الطاقة النافذة من قرص التضمين البصري .

جميع النتائج استحصلت بواساطة انشاء برنامج خاص اسميناه قرص التضمين البصري الاصدار الثالث الذي يحتوي العديد من البارمترات. جميع نماذج قرص التضمين تتألف من 20 مقطعا" ،عشرة منها مضيئة والاخرى معتمة لضوء الليزر . ان عدد المقاطع يعتمد على عوامل عديدة مثل تردد القطع، القدرة النافذة ودالة الانتقال الضمني.

وقد ثبت عن طريق المحاكاة ان افضل قيمة لدالة الانتقال الضمني تتحقق عندما يكون حجم بقعة الليزر 0.3 ملم واي زيادة في حجم المقطع يودي الى انخفاض في قيمة دالة الانتقال الضمني.

الكلمات مفتاحية : التضمين البصري الكسوري ، تردد القطع، حجم المقطع ، القدرة النافذة ، دالة الانتقال الضمني