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Influence of Apodization Pupil Function on the Intensity Point Spread Function of Optical System

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ABSTRACT

Apodization is the significant modification of the impulse response of the optical system. This modification plays a vital role in improving the imaging and focusing characteristics foe various optical systems. We present our studies on apodization of pupils with amplitude filter respect to images of point objects . The central intensity distribution, the Full width at half maximum (FWHM)of point spread function, first maxima and first minima are evaluated and compared with and without apodisation .our results shown that the resolution of the intensity of the PSF has been modified as the degree of apodization increases .

Keywords : FWHM, PSF

I. INTRODUCTION

The degree of spreading of the point object(point spread function PSF) is a measure for the quality of an imaging, it describes the response of an imaging system to a point object. The point spread function is a useful concept in astronomical imaging ,Fourier optics, , electron microscopy, fluorescence microscopy and 3D microscopy etc[1.2]. Change the pupil function of an optical system with the appropriate apodization is important role in improving the resolution of an optical system, it is a technique that modified the impulse response of the optical system[3]. several studies work on optical system that asymmetrically apodised with amplitude phase and filters. Naresh A,Sagar,D.K.. et.al.[4] evaluated FWHM for optical system suffered from large amount of aberrations . M. Venkanna et.al.[5] studied the effects of aperture obscuration and aberrations on apodization of pupils with various amplitude filters. A. N. Reddy et.al.[6] applied the concepts of the amplitude and phase diffractive optical elements to reduce the focal spot and size of the tight focusing of differently polarized laser beams. While C.Vijender [7] presented an analysis of influence of shape and transmissivity of a pupil of an optical system on an axial energy distribution. P. Anitha et.al.[8] investigated the different filters on energy parameters, they proves the s effectiveness of these filters to in suppressing side lobes of the parameters of energy. In the present paper the quality criterions of PSF and FWHM has been investigated by in the presence of amplitude apozation pupil function for various amount of amplitude apodization parameter .

Theory

The normalized diffracted complex light amplitude at the point (u, v)in the image plane associated with a rotationally symmetric pupil is given by using Fourier transform to pupil function f(x, y)[9]

$$A(u,v) = \int_y \int_x f(x,y) \cdot e^{i2\pi(ux+vy)} dxdy \text{.........(1)}$$

where *f(x, y)* is the pupil function of the optical system; u, v is the dimensionless coordinates variable which forms the distance of the point of observation from the center of diffraction head; and (x, y) is the reduced co-ordinate on the exit-pupil of the system.

$$f(x, y) = \tau(x, y) \cdot e^{ikW(x,y)} \text{.........(2)}$$

Where $\tau(x,y)$ is the pupil transparency that represents the real amplitude distribution in exit pupil ; $W(x, y)$ represent the aberration function

In the present study, we have chosen the apodized Bartlett window function that is pupil function can be represented by[10]

$f(x, y) = (1 - \beta r)$ ....(3)

where β is the apodizing parameter controlling the non-uniform transmission of the pupil.

The intensity PSF $I(u, v)$ which is the real measurable quantity can be obtained by taking the squared modulus of $A(u, v)$.

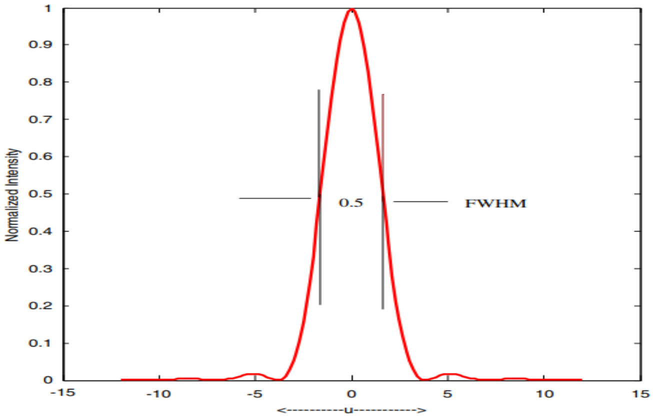
$$I(u,v) = |A(u,v)|^2 \text{ ....(4)}$$

$$I(z) = |A(z)|^2 \text{ ....(5)}$$

The dimensionless diffraction variable z = 2 π u, and m = π v

Because of the symmetry of intensity distribution ,m=0

The full width at half maximum (FWHM)[11], it is the diameter of the PSF at 50 % of its peak value. It is twice the distance of the point from the center of diffraction pattern where intensity PSF becomes one-half of maximum value. For all symmetric pupil functions, FWHM is an image quality criterion whenever the PSF is at the non-zero minimum.



Figure(1) : FWHM of Unapodized Case (Airy)[11]

II. Numerical Result s and Discussion

The effects of asymmetric apodization on the PSF have been analyzed for various values of apodization function β for optical system in the image of point object. The effect of above parameter on both FWHM and HWHM of apodized PSF have been discussed. The results have been obtained from equation (5) by employing MTHCAD . The PSF in the images been obtained for different values of z varying from –10 to +10. Figure 1 display the intensity distribution curves for the chosen amplitude filter when the aberration-free optical system is apodized in the case of circular aperture. , it is given in detail in table (1)

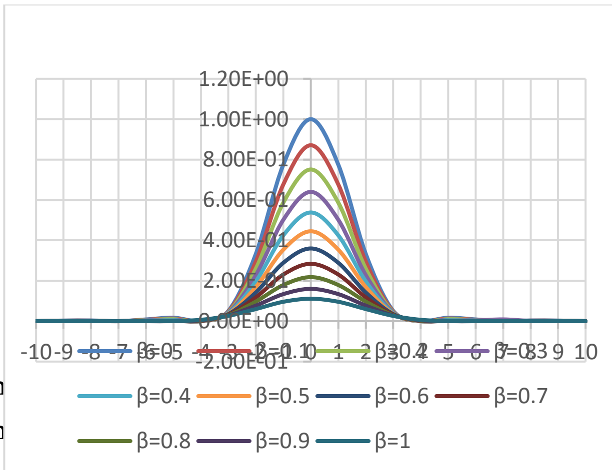


Figure (2):variation of intensity distribution with the values of β

Table(1) : values of PSF for various values of β

z	β=0	β=0.1	β=0.2	β=0.3	β=0.4	β=0.5	β=0.6	β=0.7	β=0.8	β=0.9	β=1
-10	7.56E-05	7.28E-05	7.00E-05	6.73E-05	6.46E-05	6.20E-05	5.94E-05	5.69E-05	5.45E-05	5.21E-05	4.97E-05
-9	2.97E-03	2.46E-03	2.06E-03	1.59E-03	1.22E-03	9.05E-04	6.35E-04	4.13E-04	2.38E-04	1.11E-04	3.21E-05
-8	3.44E-03	2.78E-03	2.19E-03	1.67E-03	1.22E-03	8.42E-04	5.33E-04	2.94E-04	1.28E-04	2.80E-05	4.03E-07
-7	1.79E-06	3.51E-06	5.79E-06	8.65E-06	1.21E-05	1.61E-05	2.07E-05	2.58E-05	3.15E-05	3.78E-05	4.47E-07
-6	8.51E-03	6.92E-03	5.50E-03	4.24E-03	3.14E-03	2.21E-03	1.44E-03	8.38E-04	3.96E-04	1.18E-04	3.35E-06
-5	1.70E-02	1.30E-02	9.94E-03	7.06E-03	4.67E-03	2.78E-03	1.37E-03	4.56E-04	3.23E-05	9.97E-05	6.58E-04
-4	1.09E-03	4.65E-04	1.02E-04	1.92E-06	1.65E-04	5.92E-04	1.28E-03	2.23E-03	3.45E-03	4.93E-03	6.67E-03
-3	5.10E-02	4.80E-02	4.50E-02	4.30E-02	4.00E-02	3.70E-02	3.50E-02	3.20E-02	3.00E-02	2.80E-02	2.60E-02
-2	3.33E-01	2.95E-01	2.60E-01	2.28E-01	1.97E-01	1.69E-01	1.42E-01	1.18E-01	9.70E-02	7.70E-02	6.00E-02
-1	7.75E-01	6.77E-01	5.87E-01	5.02E-01	4.25E-01	3.54E-01	2.89E-01	2.31E-01	1.79E-01	1.34E-01	9.60E-02
0	1	0.871	0.751	0.64	0.538	0.445	0.36	0.284	0.218	0.16	0.111
1	0.775	0.677	0.587	0.502	0.425	0.354	0.289	0.231	0.179	1.34E-01	0.096
2	0.333	0.295	0.26	0.228	0.197	0.169	0.142	0.118	0.097	7.70E-02	0.06
3	0.051	0.048	0.045	0.043	0.04	0.037	3.50E-02	3.20E-02	3.00E-02	2.80E-02	2.60E-02
4	1.09E-03	4.65E-04	1.02E-04	1.92E-06	1.65E-04	5.92E-04	1.28E-03	2.23E-03	3.45E-03	4.93E-03	6.67E-03
5	0.017	0.013	9.94E-03	7.06E-03	4.67E-03	2.78E-03	1.37E-03	4.56E-04	3.23E-05	9.97E-05	6.58E-04
6	8.51E-03	6.92E-03	5.50E-03	4.24E-03	3.14E-03	2.21E-03	1.44E-03	8.38E-04	3.96E-04	1.18E-04	3.35E-06
7	1.79E-06	3.51E-06	5.80E-06	8.65E-03	1.21E-05	1.61E-05	2.07E-05	2.58E-04	3.15E-05	3.77E-05	4.47E-05
8	3.44E-03	2.78E-03	2.19E-03	1.67E-03	1.22E-03	8.42E-04	5.33E-04	2.94E-04	1.26E-04	2.80E-05	4.03E-07
9	2.97E-03	2.46E-03	2.00E-03	1.59E-03	1.22E-03	9.05E-04	6.35E-04	4.13E-04	2.38E-04	1.11E-04	3.21E-05
10	7.56E-05	7.28E-05	7.00E-05	6.73E-05	6.46E-05	6.20E-05	5.94E-05	5.69E-05	5.44E-05	5.21E-05	4.97E-05

From both the figure and the table and it is evident that the value of PSF decreases with increase in the value of the apodization parameter β. This implies that the quality of the point image is degraded steadily as the value of β is increased. Applying the Marechal criterion to the results obtained in this paper [12] , we find that, in order to obtain a good quality image of point object, by the system considered using the filter, the value of β must be within the range 0 ≤ β ≤ 0.2.

In the table-2, we have presented the computed values of the a quality assessment parameter FWHM and the HWHM , which describes distribution of half maximum area on good and bad side of PSF of asymmetric apodization for selected values of the apodisation parameterβ. From Listed values in this table FWHM decreases from 3.5 to 3.4 with increase the values of β.This information is very important while studying the Two-point Resolution capabilities of the optical system.

Table 2: FWHM and HWHM of apodised PSF for the values of β

β	PSF	FWHM	HWHM
0	1	3.5	1.75
0.1	0.871	3.4	1.7
0.2	0.751	3.44	1.72
0.3	0.64	3.4	1.7

III. Conclusions

The present study found that when an optical system is apodized with amplitude filter, it can modify the resolution of the intensity redistribution of the PSF. As the degree of apodization increases, the amount of light flux entering the system decreases, the intensity of central maximum falls and its width increases. The attenuation in the intensity of optical side lobes is the principal intended result of apodization, For lower values of Beta in the range 0 ≤ β ≤ 0.25 the FWHM is lower than that of airy case . In this way we succeeded improves the performance of optical systems by improving the axial resolution.

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