Setting the Point Spread Functions of Aberrated Optical Systems Intensity Distribution to Your Needs in the Presence of Defocus

[1] **Malathi,** [2]**Nirmala Mary,** [3]**P.Narendar**
[1,2,3]Assistant Professor, [1,2,3]Department of H & S, Visvesvaraya College of Engineering & Technology, Hyderabad,India

Abstract
The radius of the first dark ring in the point spread function is important. One of the main merit functions connected to point spread functions is this one. Our research involves calculating the size of the first black ring in the produced point image's diffraction pattern. We have thought about amplitude and phase filters for shading apertures. The filter's impact on achieving the smallest feasible radius for the first dark ring, which in turn affects the resolving capabilities of optical imaging systems, has been studied in order to determine the ideal value of apodization for a particular aperture..
Keywords: Rotationally Symmetric Systems, Hanning amplitude filters, Super- resolution.

INTRODUCTION

The suppression of secondary side-lobes in the diffraction pattern, also known as the point spread function (PSF), is highly desirable in some circumstances in the current photonics era, where there is a wide surge of advancement of optics penetrating into all forms of technological development, especially in the field of optical imaging and telecommunications. Apodization is the method that is used to accomplish this. The intensity in the outer regions of the diffraction pattern can be completely suppressed or at least significantly lowered without extending the pupil's size by carefully selecting the transmission function of the system's pupil. In instrumental optics, several apodization filters have been suggested for a variety of uses[1]. In the present investigation, the diffracted field characteristics of rotationally symmetric optical systems shaded with the variable apodisation with two zones have been considered to analyze the intensity distribution in terms of the width of the central maximum and reduction in the secondary maxima by shaping the circular aperture into two-zone aperture with varying central circular zone parameter. Hence, the study of imaging properties of optical systems from the knowledge of the PSF has become an important method in the design and testing of such systems [2].

EXPERIMENTAL

The far-field diffraction characteristics due to a circular aperture in an optical imaging system can be derived from its amplitude response or the amplitude PSF. The diffracted light amplitude associated with a rotationally symmetric pupil is given by [3],

$$A(Z) = 2\int_0^1 f(r) J_0(Zr) r dr \qquad (1)$$

Where f(r) is the pupil function of the optical system; Z is the dimensionless variable which forms the distance of the point of observation from the centre of diffraction head; and $J_0(Zr)$ is the zero order Bessel function of the first kind; „r" is the reduced co-ordinate on the exit-pupil of the system. The expression for annular aperture can be written as

$$A(Z) = 2\left[\int_0^a 0.54 + 46\cos(\pi\beta\, r) J_0(Zr) r dr + \int_a^b \cos(\pi\beta\, r) J_0(Zr) r dr \right] \qquad (2)$$

In the present study, we have considered the variable apodisation with two filters one Happ-genzel amplitude filter in the central zone and whose pupil function can be represented by

$f(r)$ □ 0.54 + 46 cos(□□ r) ; In the inner zone and with $f(r)$ □ cos(□□ r) at the outer zone.

Where □ is the apodising parameter controlling the non-uniform transmission of the pupil. The intensity PSF B(Z) which is the real measurable quantity can be obtained by taking the squared modulus of A(Z). Thus,

$$B(Z) = |A(Z)|^2 \qquad (3)$$

RESULTS AND DISCUSSION

Expressions (2) and (3) have been used to compute the point spread functions of the apodised apertures with variable apodisation using two amplitude filters. Figure 1 depicts the intensity distribution curves for various degrees of apodisation parameter for two-zone circular aperture (a=0.5) with Happ-genzel filter in the inner zone and Hanning filter in the outer zone. Form the profile of the intensity distribution curves it is evident that for β = 0.50, i.e., for partial apodisation there appears to be a total elimination of the optical side-lobes thus shaping thepoint spread function to the desired profile. However, for extreme apodisation β = 1, theintensity in the central lobe tailors to the desired profile there by an increase in the intensity of the central maximum and reduction in the value of full width at half maxima (FWHM) is the outcome by employing the variable apodisation .Table-1 provides the computed values of the radius of the first, second and third dark rings for circular aperture in the case of first order filter for different values of β.

FIGURE1. Intensity distribution curves for aperture with variable apodisation.

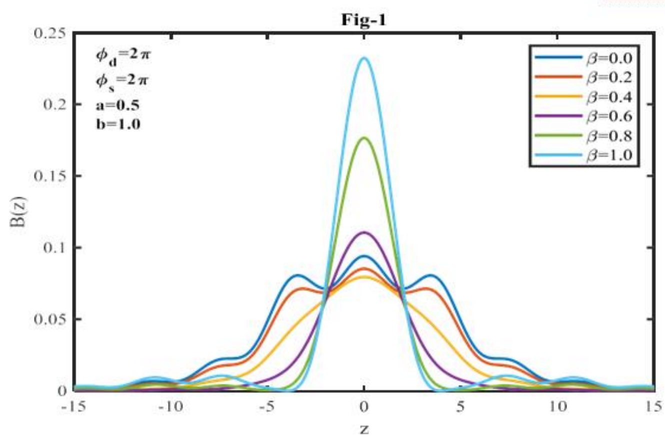


TABLE 1.

β	First Minima Position Position	Second Minima Position	Third Minima
0.00	3.8317	7.0154	10.1728
0.10	3,8581	7.0300	10.1833
0.20	3.9463	7.0797	10.2179
0.30	4.1310	7.1928	10.2980
0.40	4.5124	7.4836	10.5218
0.50	5.3304	8.5378	11.7073
0.60	6.1977	9.6078	12.8801
0.70	3.3443	7.9745	11.3037
0.80	1.5484	6.7172	9.9824
0.90	2.1656	6.8507	10.0735
1.00	2.4560	6.9826	10.1631

FIGURE2: Intensity distribution curves for aperture with a =0.6

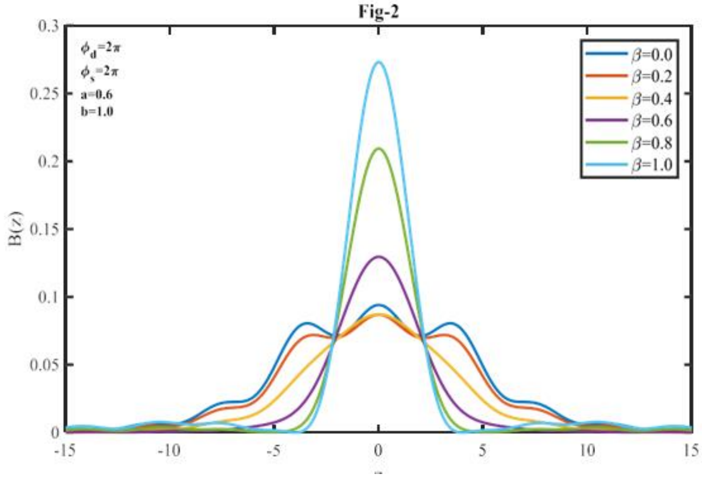


Figure 2 depicts the intensity distribution curves for various amounts of apodisation parameter for two-zone circular aperture (a=0.6) with Happ-genzel filter in the inner zone and Hanning filter in the outer zone. For the profile of the intensity distribution

z

curves it is evident that for β = 0.50, i.e., for partial apodisation there appears to be a total elimination of theoptical side-lobes and for higher values of apodisation with β = 1, the intensity in the centrallobe shapes to the desired profile resulting in an increase in the intensity of the central maximumand reduction in the reduction in the radius of the first dark ring , in other words the energy in the central maximum is increase with reduced size of the spot rendering it to be super-resolved.

FIGURE3: Intensity distribution curves for aperture with a =0.7

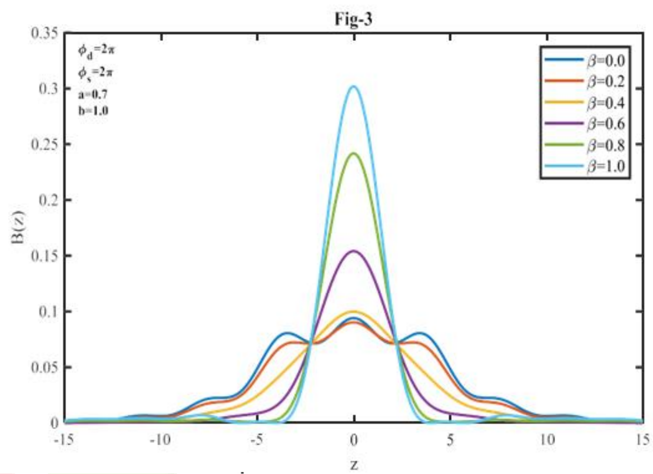
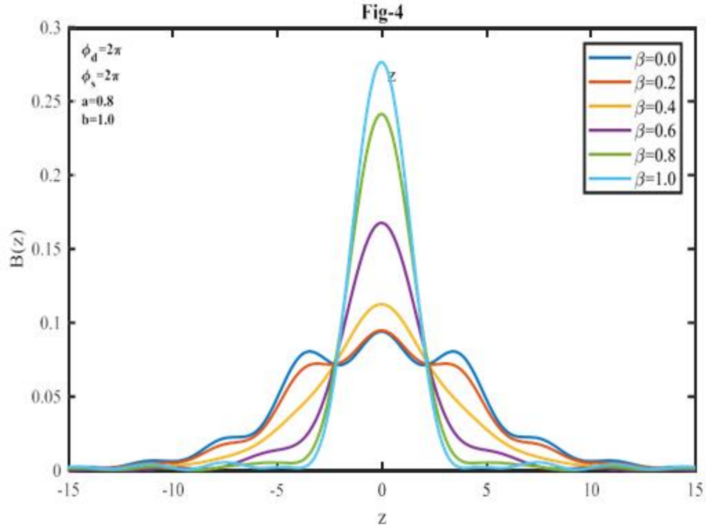


FIGURE4: Intensity distribution curves for aperture with a = 0.8

Fig-4



Figures 3 and 4 depicts the intensity distribution curves for central zone with a = 0.7 and a = 0.8

Conclusions

z

The optical side-lobes are completely or partially suppressed during the apodization process using a variable apodization amplitude filter. These side-lobes are completely removed for all four orders of the optical filter under consideration for = 0.5. The radius of the Airy disc is lowered below the traditional limit of 3.8317 due to a central blockage. For two-zone apertures (a = 0.5), the radius of the first dark ring for clear apertures is reduced by around one-third. The power of the optical side-lobes grows as a result of energy being transferred from the Airy disc to the surrounding rings. A feature that effectively shapes the point spread function of the specified optical systems is produced by using Happ-genzel amplitude filters in the core zone and Hanning amplitude filters in the outer zone.

REFERENCES

[1] Mills, JP. Thompson, BJ. Selected papers on apodization:coherent optical systems - Washington: "SPIE Optical Engineering Press" Publisher, 1996. – Vol.119.

[2] Jacquinot, P. Roizen-dossier, B. Apodization. Progress in Optics, 1964. - Vol.3. – P. 29-32.

[3] Barakat, R. Application of apodization to increase Two-point resolution by Sparrow criterion under incoherent illumination. J. Opt. Soc. Am., 1962. – Vol.52. – P. 276-283.

[4] Barakat, R. Solution to the Lunenberg Apodization problems. J. Opt. Soc. Am., 1962. – Vol.52. – P. 264-272.

[5] Khonina, SN. Ustinov, AV., and Pelevina, EA. Analysis of wave aberration influence on reducing the focal spot size in a High-aperture focusing system. J. Opt., 2011. – Vol.13. – 13pp.

[6] Falconi, O. The limits to which double lines, Double stars, and Disks can be resolved and measured. J. Opt. Soc. Am., 1967. – Vol.57(8). –P. 987.

[7] Hopkins, HH. Zalar, B. Aberration tolerances based on Line spread function. J. Mod. Opt., 1987. – Vol.34(3). – P. 371-406.

[8] Gupta, AK. Singh, K. Partially coherent far-field diffraction in the presence of primary astigmatism. Can. J. Phys., 1978. – Vol.56. – P. 1539-1544.

[9] Andrew Watson, B. Computing human optical Point spread functions. Journal of Vision, 2015. – Vol.15(2). – P. 1-25.

[10] Khorin, PA. Khonina, SN. Karsakov, AV. Branchevskiy, SL. Analysis of corneal aberration of the human eye. Computer Optics, 2016. –Vol. 40(6). – P. 810-817.

[11] Asakura, T. Resolution of two unequally bright points with partially coherent light. Nouv. Rev. Opt., 1974. – Vol.5(3). – P. 169-177.

[12] Asakura, T. Ueno, T. Apodization for increasing two-point resolution by the sparrow criterion under the partially coherent illumination. Nouv. Rev. Opt., 1974. – Vol.5(6). – P. 349-359.

[13] Karuna Sagar, D. Sayanna, R. and Goud, SL. Effects of defocusing on the sparrow limits for apodized optical systems. Opt. Commun., 2003. – Vol.217. – P. 59-67.

[14] Naresh Kumar Reddy, A. Karuna Sagar, D. Point spread function of optical systems apodised by a semicircular array of 2D Aperture functions with asymmetric apodization. Journal of Information and Communication Convergence

Engineering, 2012. – Vol.12(2). – P. 83-88.
[15] Keshavulu Goud, M. Komala, R. Naresh Kumar Reddy, A. and Goud, SL. Point spread function of asymmetrically apodised optical systems with complex Pupil filters. Acta Physica Polonica A, 2012. – Vol.122(1). – P. 90-95.
[16] Kowalczyk, M. Zapata-Rodriguez, CJ. Martinez-Corral, M. Asymmetric apodization in confocal scanning systems. Applied Optics, 1998. – Vol.37(35). – P. 8206-8214.
[17] Siu, GG. Cheng, L. Chiu, DS. Improved side-lobe suppression in asymmetric apodization. J. Phys. D: Applied Physics, 1994. – Vol.27(3). –P. 459-463.
[18] Cheng, L. Siu,GG. Asymmetric apodization. Measurement and Technology, 1991. – Vol.2(3). – P. 198-202.
[19] Naresh Kumar Reddy, A. Karuna Sagar, D. Defocused point spread function of asymmetrically apodized optical systems with slit apertures. Journal of Biomedical Photonics & Eng., 2016. – Vol.2(3). – P. 1-6.
[20] Naresh Kumar Reddy, A. Karuna Sagar, D. Spherical aberration of point spread function with Asymmetric pupil mask. Advances in Optical technologies, 2016. – Vol.2016. – P.1-5.