Intensity Distribution for Spread Function in Two Line Resolution

[1] G. Krishnaiah, [2] M Amaranath, [3] Dr. T. Kiran Kumar

[1] **Research Scholar**, BEST Innovation University, Gorantla, A. P 515231 and Assistant Professor of Physics, MALD Govt. Degree College, Gadwal, and Jogulamba Gadwal-dist. Telangana State, India

[2] **Research Scholar**, BEST Innovation University, Gorantla, A.P 515231 Asst. Professor, Department of Physics, Annamacharya Institute of Technology and Sciences, Hyderabad- 501512, Telangana, India

[3] **Research Supervisor**, Assistant Professor, Department of Physics, Brilliant Institute of Engineering and Technology, Hyderabad, India

Corresponding Author: T. Kiran Kumar

Abstract: According to sparrow criterion, two-point sources are said to be resolved when the second derivative of the total distribution of irradiance in the diffracted image of the two- points, vanishes at a point midway between the respective Gaussian image points. When this condition is satisfied, the distance between the two object points gives the sparrow limit of resolution. In the resultant irradiance distribution curve, the central dip just vanishes when the resolution begins. Initially the dip is at the middle point between the two Gaussian image points when the separation between two-point object is larger than the critical limit. As the distance between the points is reduced, the dip reduces in its upward concavity and it just vanishes at a particular separation of the two-point objects.

Key words: Defocus, Aberration, Intensity ,Two-line resolution; Intensity distribution; Spread function; Line spread function; Point spread function; Diffraction; Optical imaging system; Rayleigh criterion; etc.

1. Introduction

In the resolution of an optical system, the Two Lines Resolution plays an important role. According to Raleigh criterion of resolution, the resolving power increases as the first minimum of the Point Spread Function moves towards the center of the pattern. It means the resolution of an optical system can be judged from the knowledge of the PSF of the system. Thus, the more fundamental parameter to be studied.

The Two Lines Resolution is a three-dimensional function. In this study the Two Lines Resolution is considered as a two-dimensional function since the optics deals with two-dimensional signals and due to the particular importance of the effect of diffraction or aberration or both on the optical imaging system can be specified by the Point Spread Function.

It is necessary to obtain qualitative and quantitative information regarding the imaging systems in order to evaluate their performance. In the image field science, there are two well-defined and developed functions to analyze the performance of an optical system in the image formation on the basis of diffraction theory.

These two are point spread function (PSF) and optical transfer function (OTF). The point spread function is an important tool in modern optical design and evaluation of an image. Increasing use of colour in education has raised concerns for children, but robust evidence is lacking (B. Guan, H. Yu, W. Song, 2021).

The analysis of PSF still attracts many investigators because it provides criteria concerning image performance that are directly related to the image formation of the lens system. The beam expands less in the direction of higher anisotropy coefficient. The inner scale shows an influence on the ellipticity of the beam (L. C. Andrews, R. L. Phillips, R. Crabbs, 2013).

By considering the point spread function as a measure of the energy scatter, considering that two adjacent terms in the power expansion have opposite sign the error made by contraction of the mentioned summation procedures can be easily estimated (MAGIERA, MAGIERA and PLUTA, 1980) have analyzed and determined the position of the best focal plane for defocusing and spherical aberrations.

The effect of focus error on any diffraction-limited image has been described in terms of an operator (OJEDA ,1983). This permits the diffraction of special functions to analyze the effect of focus on the PSF. The effect of the aberration function on the diffraction image produced by an optical system has been studied thoroughly by Nijboer, Mahan, etc., (BORN and WOLF, 1984). STANISLAW has derived an approximate PSF formula for an illuminated circular pupil with rotationally symmetric aberrations.

2. Literature Review

The point and line spread functions in diffraction theory, which describes image generation, have been used extensively to study two-line resolution. Resolvability and the intensity distribution of overlapping spread functions are related by classical resolution criteria like Rayleigh's limit. Subsequent research revealed that two-line resolution is directly impacted by system characteristics and aberrations, which alter the spread function form.

3. Methodology:

The model of the optical system is shift-invariant and linear. Delta functions that are separated by a predetermined distance are used to represent two line objects. By convolving the object with the system's line spread function, two shifted spread functions are superposed, yielding the picture intensity distribution. The Rayleigh criterion is used to assess resolution and examine the overlap of intensity profiles by varying the line separation.

4. **Mathematical Formulation**

The Two Lines Resolution study also describes the effect of image motion. Atmosphere turbulence and other external factors. Which are treating as degrading parameter of optical system. Throughout this thesis quasi-monochromatic Two Lines Resolution is considered.

Polychromatic Point Spread Function can be defined if the point source object has the wavelength range more than its average wavelength (M. Born and E. Wolf, 1999). We outline the procedure and associated accuracy for calibrating display devices, and the psychophysics and design of resolution. We present results evaluating resolution in a two-stage design that ensures that its validation is based on data (M. I. Suero, A. L. Pérez, F. Díaz, 2005).

The integral with respect to θ is easily recognized as one occurring in connection with the Fraunhofer diffraction pattern at a circular aperture. It is equal to $2\pi J_0$ (Z r), where J_0 is the Bessel function of the first kind and zero order. Higher levels of frustration, and lower confidence ratings in the simulation condition (Hopkins, H. H., 1955).

$$G_F\left(P\right)=-\frac{iA}{\lambda}\frac{a^2}{s^2}\exp\left(i\frac{s^2}{a^2}Y\right)2\pi\int_0^1 f\left(r\right)\exp\left[-\frac{1}{2}i\phi_d r^2-\frac{1}{4}i\varphi_S r^4-\frac{1}{3}i\Phi_C r^3 Cos^3\theta\right]J_0\left(Zr\right)rdr$$

Let $\Omega=\frac{A}{\lambda s^2}\exp\left[i\frac{s^2}{a^2}Y\right]$ The above expression then becomes

$$G_F\left(P\right)=2\pi i\Omega a^2\int_0^1 f\left(r\right)\exp\left[-\frac{1}{2}i\phi_d r^2-\frac{1}{4}i\varphi_S r^4-\frac{1}{3}i\Phi_C r^3 Cos^3\theta\right]J_0\left(Zr\right)rdr$$

In the expression theright-hand side $G_F(P)$ is a function of $\Phi_d,\ \varphi_s,\ \Phi_c$ and Z. Hence it may be replaced by $G_F = (\Phi_d,\ \varphi_s,\ \Phi_c, Z)$ to give the sparrow resolution limit increases as the degree of coherence increases, irrespective of the intensity ratio of two-point objects.

With respect to intensity ratio of two points (Li, H., & Ojeda-Castañeda, J.,1994). A stationary and linear optical systems with incoherent illuminator described as a convolution of intensity distribution GF(P) of the object with the intensity point spread functionΦd of the optical system (Leon Magiera, Mieczysław, 1981).Our approach can be rephrased heuristically as follows.

If one prevents an image to become badly degraded, its restored version has higher quality than the restored picture of the non-preventive image. In the case of focus errors, the image exhibits high focal depth (Ojeda-Castañeda, J., & García, M., 1985).

$$(\phi_d, \varphi_S, \Phi_c, Z) = 2\pi i\Omega a^2 \int_0^1 f(r)\exp\left[-\frac{1}{2}i\phi_d r^2 - \frac{1}{4}i\varphi_S r^4 - \frac{1}{3}i\Phi_C r^3 Cos^3\theta\right] J_0(Zr) r dr$$

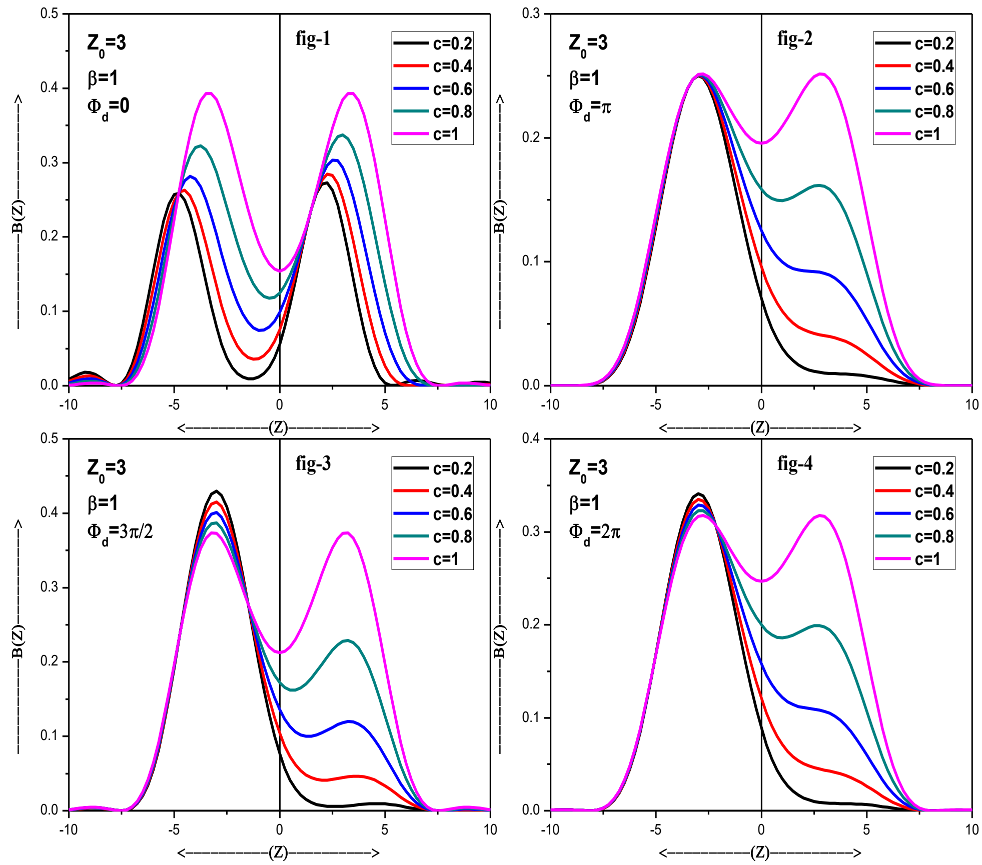
Knowledge of Gaussian optics and an appreciation for aberrations would be useful but is not required. The second edition of Aberration Theory Made Simple features an updated Cartesian sign convention, which is used in advanced books on geometrical optics and in optical design software (Mahajan, V. N., 1983).

The exact diffraction optical transfer function and point spread function are compared to the geometrical OTF and PSF, respectively, for both small and large amounts of defocusing. It follows that geometrical optics does not describe diffraction optics very well for any reasonable and the defocus aberrations from $\phi_d = 0$ to $\phi_d = 2\pi$.

β=1 **Table - 1**

	C = 0.2		C= 0.6		C = 1.0	
	SL	RL	SL	RL	SL	RL
$\phi_d = 0$	2.504	3.196	2.854	3.317	2.538	3.129
	2.824	3.543	3.166	3.621	2.834	3.428
	3.222	3.861	3.474	3.907	3.131	3.711
	3.603	4.168	3.786	4.184	3.44	3.984
	3.955	4.464	4.112	4.446	3.776	4.251
	3.79	5.88	4.385	4.619	4.181	4.496
$\phi_d = \pi$	3.12	3.717	3.077	3.604	2.662	3.351
	3.472	4.029	3.388	3.899	2.963	3.649
	3.79	4.294	3.686	4.164	3.259	3.92
	4.066	4.496	3.972	4.394	3.559	4.166
	4.206	5.8	4.239	4.574	3.873	4.384
	4.011	6.001	4.402	4.67	4.218	4.558
$\phi_d = 2\pi$	3.299	3.888	3.147	3.7	2.699	3.425
	3.637	4.187	3.459	3.995	3.003	3.725
	3.941	4.429	3.757	4.254	3.301	3.994
	4.186	4.58	4.038	4.47	3.602	4.234

	4.218	**5.808**	**4.291**	**4.629**	**3.914**	**4.441**
	4.074	**6.004**	**4.427**	**4.709**	**4.253**	**4.6**



5. Results and Discussions:

Within the scope of the study the following conclusions may be drawn from the Table -1 and graphs are drawn for the spherical aberrations for intensity ratios c=0.2 to 1 in the increments of 0.2 which are depicted in the figures keeping the defocus parameter from π to 2πFrom 3 the value at c=0.2 show much intensity and in the figure 4it is decreasing and the table values for $\phi_d = 2\pi$ at the high degree of apodisation the defocus aberrationfrom πto 2π we are getting resolution but in the figure -1 there is no resolution for the aperture and in the Table -1 the values are taken for the c variation are studied and the values are up to 4.6 at c=1.

6. Conclusion:

The spread function's intensity distribution at two-line resolution demonstrates that the superposition of two shifted spread functions creates the image. Resolution is lost when the line spacing gets smaller because more overlap lessens the intensity dip between peaks. The just-resolved lines' limited separation is indicated by the Rayleigh criterion. The research demonstrates that the resolving power of optical imaging systems is essentially determined by the properties of the diffraction and spread functions.

References:

1. B.Guan, H. Yu, W. Song, et al., Spatial Property of Optical Wave Propagation through Anisotropic Atmospheric Turbulence (Wiley, Hindawi Wireless Communications and Mobile Computing, 2021).Volume 2021,Article ID 5519786,
2. D.A. Paulson, Daniel A "Experimental characterization of atmospheric turbulence supported by advanced phase Screen simulations," Dissertation submitted to the Faculty of the Graduate School of the University of Maryland,
3. Hopkins, H. H. "The Frequency Response of a Defocused Optical System." Proceedings of the Royal Society A, 231(1184), pp. 91–103, 1955.
4. Leon Magiera, Mieczysław Pluta Institute of Physics, Technical University of Wroclaw, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland. Optica Applicata, Vol. XI, No. 2, 1981.
5. Li, H., & Ojeda-Castañeda, J. "Two-line resolution in optical systems with apodization." Applied Optics, 33(34),pp. 8031–8038, 1994.
6. L.C. Andrews, R. L. Phillips, R. Crabbs, et al., "Deep turbulence propagation of a Gaussian-beam wave in anisotropic non-Kolmogorov turbulence," Proc. SPIE 8874, 887402,
7. Mahajan, V. N. "Aberration Theory Made Simple." SPIE Press, Second Edition, Page xv, Virendra N. Mahajan, El Segundo, California, 1983.
8. M. Beason, L. Andrew, and I. Toselli, "Calculating structure function constant from Measured Cn2 in non-Kolmogorov and anisotropic turbulence including inner scale Effects," Appl. Opt. 58, pp.6813–6819, 2019.
9. M. Born and E. Wolf, Principles of Optics, 7th ed., Cambridge, New York, 1999.
10. M. I. Suero, A. L. Pérez, F. Díaz, et al., "Does Daltonism influence young children's learning?" Learn. Individ. Differ. 15, pp. 89–98, 2005.
11. 11 Ojeda-Castañeda, J., & García, M. "Two-line resolution and apodisation filters." Optik, 71(4), pp. 131–137, 1985.
12. P. Cumberland, J. S. Rahi, and C. S. Peckham, "Impact of congenital colour vision deficiency on education and Unintentional injuries: findings from the 1958 British birth cohort," BMJ 329, pp. 1074–1075, 2004.
13. Stokseth, P. A. (1969). "Properties of a Defocused Optical System." Journal of the Optical Society of America, 59(10), 1314–1321.