IOSR Journal Of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 16, Issue 4 Ser. 1 (July. – August. 2024), PP 48-52
www.Iosrjournals.Org

Two Point Resolution Of An Optical Imaging System With Truncated Apertures

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Abstract
Intensity distribution of any imaging system initially depends on the type of the aperture. Light flux passing through an aperture changes with its geometrical shape; so shaping an aperture itself acts as an apodizer. In this paper, resolution of two point objects having unequal and equal intensities has been investigated under various coherence illumination with truncated apertures in the case of aberration free with defocus and primary spherical aberration.
Key words:- *Two point resolution, Truncation of circular aperture, coherence, primary aberrations*

Date of Submission: 25-07-2024 Date of Acceptance: 05-08-2024

I. Introduction

Apertures with different pupil transmission functions play a vital role in modifying the point spread function of optical imaging system. Daina Nyyssonen Grimes and Brain J.Thompson[1] explained the two point resolution of two equally bright points with partially Coherent Light. Toshimitsu, Asakura studied the resolution of two unequally bright points with partially coherent light[2]. B.N.Gupta and R.S, .SIROHI and V.P.Nayyar studied the two point resolution of an annular aperture[3]. V.P.Nayyar,B.L MEHTHA and MC DUBEY investigated on Resolution of a centrally obstructed circular aperture in a partially coherent light[4].V.P.NAYYAR studied The Two-Point sparrow limit of resolution of a semi-transparent and π-phase annular aperture operating in partially coherent light[5]. B.L Mehra studied Two Point resolution with non-uniform illumination by partially coherent light[6].Hubert F.A.Tschunko studied on the Annular apertures with low and high obstuctions[7]. Keshavulu, R.Sayanna,D.Karuna Sagar,S.LGoud,studied on Effects of defocusing on the Sparrow limits for apodized optical systems[8].A.N.K.Reddy etal investigated the effect of truncated apodizers in the presence of primary aberrations[9]. Manda.Venkateshwarlu and D.Karuna Sagar studied on Optical filter in increasing Two Point resolution of Optical imaging system[10]. A.N.K.Reddy and Dasari Karunasagar studied Two-Point resolution of Asymmertically apodized optical systems[11]. A.N.K Reddy etal inestigated on effect of aberrations on the point spread function and two point resolution with versatile apodization pupils[12]. work on two point resolution is only confined to equal intensity under various coherence illumination; the effect of background intensity(side lobe intensity) of main peak not been considered . At higher intensity difference side(*α=0.2)* in addition to the limit of resolution, the intensity of 1st diffraction side loob is also a considerable parameter to decide the resolution ability of optical system. Therefore, in this paper we considered the background intensity and investigated the two point resolution of optical imaging system under various degree of coherence for aberration free and aberrated imaging system of various intensity ratios.. For this investigation we selected the truncated aperture with various truncation ratios(ε=0.00.05,0.1,0.15 and 0.2).

II. Theory

The amplitude response function in the case of defocus and spherical aberration can be expressed as

$$G\left(\emptyset_d,\emptyset_s,Z\pm\frac{Z_o}{2}\right)=2\int_0^{1-\varepsilon}e^{-i\left(\emptyset_d\frac{r^2}{2}+\emptyset_s\frac{r^4}{4}\right)}\left[G\left(Z+\frac{Z_o}{2}\right)+\alpha G\left(Z-\frac{Z_o}{2}\right)+2\sqrt{\alpha}\,\gamma G\left(Z+\frac{Z_o}{2}\right)G\left(Z-\frac{Z_o}{2}\right)\right]\quad(1)$$

Where $\emptyset_d,\emptyset_s$ are the defocus and spherical aberration parameter. Z is the reduced dimensionless diffraction coordinate, $\frac{Z_o}{2}$ is the position of two point objects on both sides of the optical axis. $G\left(Z-\frac{Z_o}{2}\right)$ and $G\left(Z+\frac{Z_o}{2}\right)$ are the amplitude response of the optical system, α is the ratio of intensity taken as 0.2,0.4,0.6,0.8,1.0, γ is the degree of coherence , γ=0 is non coherence illumination, γ=0.6 for partial coherence and γ=1 for full of coherence,ε is ratio of truncation

$$I(Z)=\left|G\left(\emptyset_d,\emptyset_s,Z\pm\frac{Z_o}{2}\right)\right|^2\qquad(2)$$

for resultant intensity distribution of two point objects at a distance of Z_o apart is given as

$$I(Z) = \left|G\left(Z - \frac{Z_o}{2}\right)\right|^2 + \alpha\left|G\left(Z + \frac{Z_o}{2}\right)\right|^2 + 2\gamma\sqrt{\alpha}\left|G\left(Z - \frac{Z_o}{2}\right)\right|^2\left|G\left(Z + \frac{Z_o}{2}\right)\right|^2 \qquad (3)$$

III. Results And Discussions

Fig.1.0 to Fig.1.4 shows the variation of intensity distribution of optical imaging system for various apertures in the case of aberration free, incoherence illumination of unapodized apertures . In the case of circular aperture ,irrespective of intensity ratio the two point objects are clearly resolved by a clear dip and with increase in the intensity ratio, the resolution increases for all the cases.

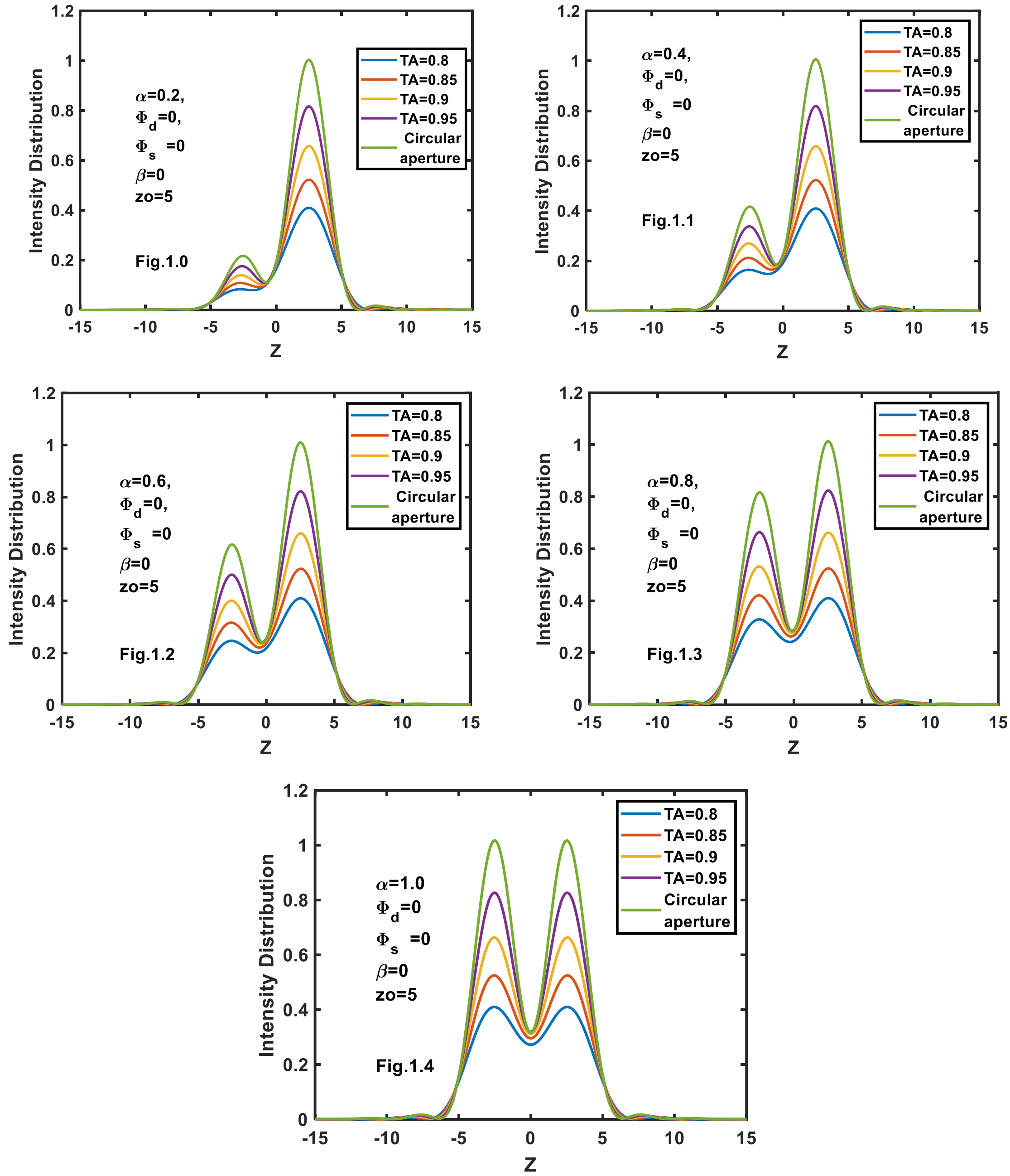
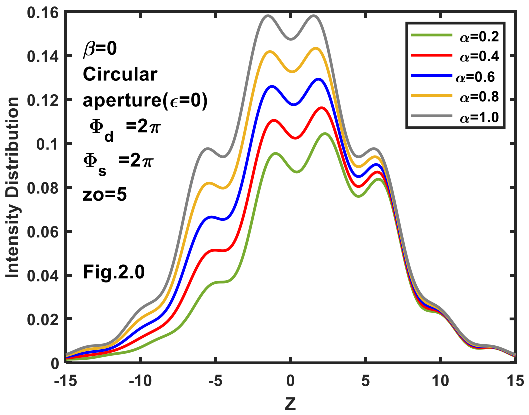


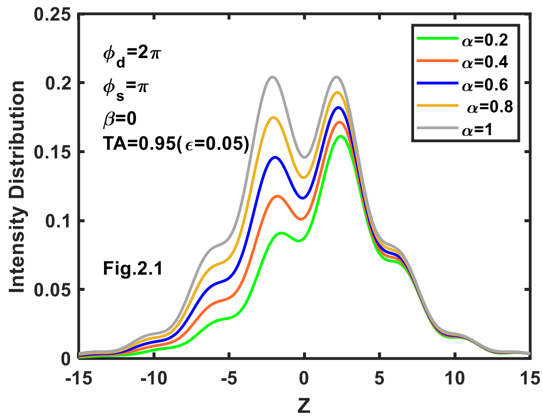
Fig1. Intensity distribution of optical imaging system with free of aberrations for various intensity ratios

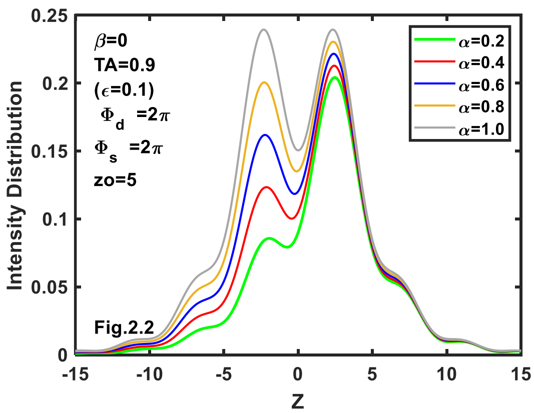
With increase in the truncation ratio, the resolution increases. For lower intensity ration with $\alpha = 0.2$, $\varepsilon = 0.2$ (TA=0.8) dip disappears thereby the two points are said to be resolved in terms of sparrow limit.

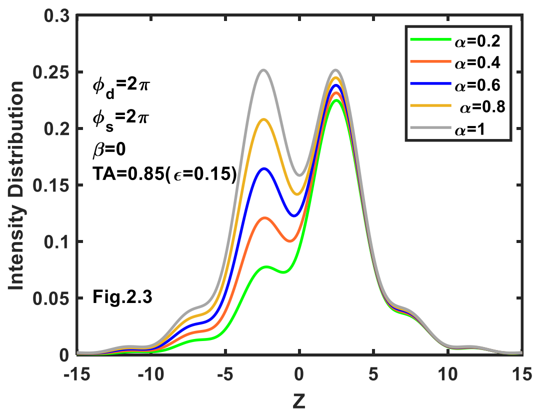
Fig.2.0 shows the intensity distribution of imaging system with circular aperture for higher values of defocus and primary spherical aberration for various intensity ratios. At highest intensity difference of two object points, ie α=0.2 magnitude of intensity of side lobes on either sides of principle maxima is very high as comparing with Fig.1.0. It leads to degradation in resolving the two point objects. Similar scenario is observed for other intensity ratios also. This problem has been overcome by replacing the circular aperture with truncated apertures with truncation ratio ε=0.0 (TA=1.0 or Circular aperture), ε=0.05 (TA=0.95), 0.1(TA=0.9), 0.15 (TA=0.85) and 0.2 (TA=0.8). Fig2.1 to Fig2.5 shows intensity distribution of imaging system with truncated apertures. Fig.2.6 exclusively depicts the intensity variation of 1st side lobe at brighter object side, Fig.2.7 illustrates the intensity of dull object with truncation. The change of intensity (in percentage) of 1st side lobe with truncation, dull object intensity, and percentage of Dull object intensity w.r.t to 1st side lobe intensity at bright point side are calculated and tabulated in table1.0. In circular aperture, intensity of 1st side lobe is 0.0830, percentage of dull object intensity with respect to 1st side lobe is only 15%. As increasing truncation ratio side lobe intensity decreasing and Dull object intensity w.r.t to 1st side lobe intensity at bright point side is increasing .Among the four truncated apertures, 0.8 truncated aperture side lobe intensity is small(27%) , the intensity of dull object with respect to 1st side lobe intensity is more(197%) as compared with circular aperture. In addition to that we observed an increase in intensity of bright object principle maxima and rapid decrease in the intensity of side lobe with truncation.

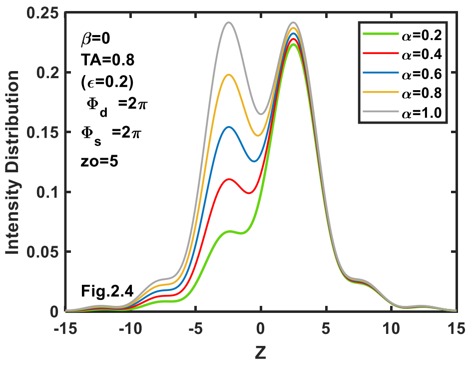
Moving from higher intensity difference to lower intensity difference dip point between two principle maximas is increasing as compared with fig2.0. These variations reflects the improvement in resolution of an imaging system

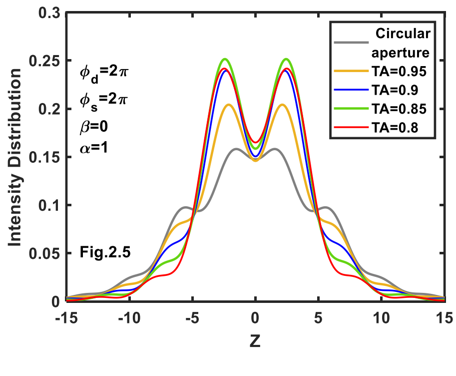












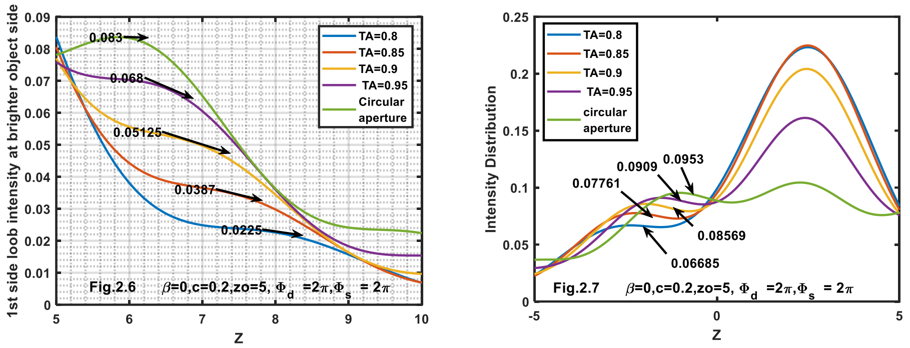
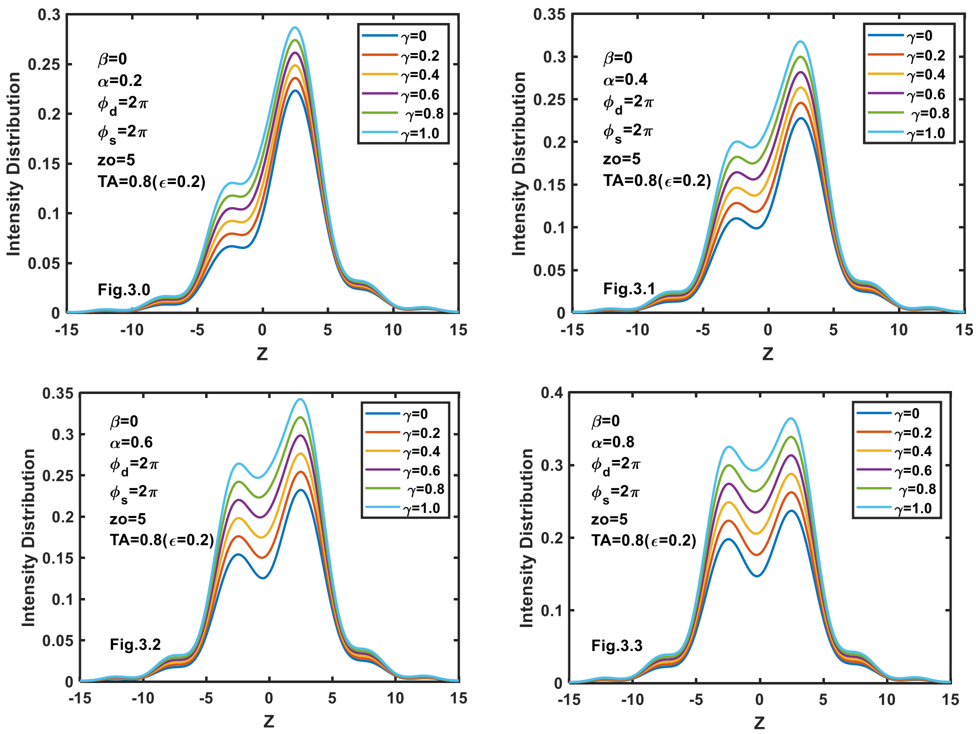


Fig2. Intensity distribution of optical imaging system with aberrations for various intensity ratios

Table.1.0

Aperture ↓	1st side loob intensity at bright point side	% of 1st side loob intensity with circular aperture	Dull object intensity	% of Dull object intensity w.r.t to 1st side loob intensity (at bright point side)
TA=0.8	0.0225	27%	0.06685	197%
TA=0.85	0.0387	47%	0.07761	101%
TA=0.9	0.05125	62%	0.08569	67%
TA=0.95	0.0680	82%	0.0909	34%
Circular Aperture(TA=1)	0.0830	100%	0.0953	15%

The intensity distribution of Truncated aperture (TA=0.8) with full of defocus and primary spherical aberration is also investigated under various degree of coherence. Fig.3.0 to Fig3.4 shows the variation of intensity distribution. From this figure it clear that with increasing coherence the intensity distribution is shifting along axial axis and dip is decreasing as compared with incoherence illumination. It is noted that resolving power is decreasing with coherence.



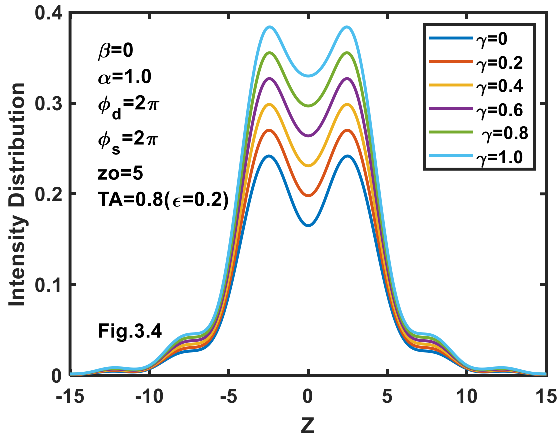


Fig.3 Intensity distribution of optical imaging system for various intensity ratios with aberrations and full of Coherent illumination

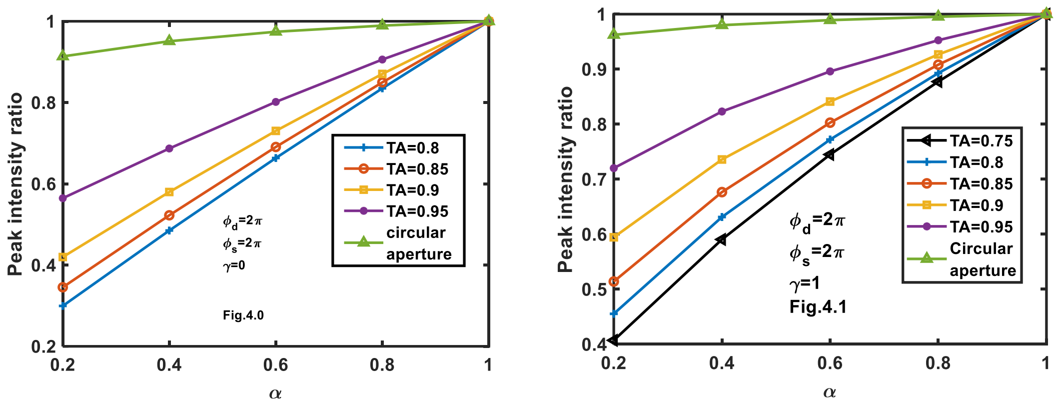


Fig.4 Peak intensity ratio as a function of intensity ratio with out and with coherence

Fig.4.0,Fig4.1 shows the peak intensity ratios as a function of 'α'. From this figure the value of peak intensity ratio increasing linearly in the case of truncated apertures for incoherent illumination. In circular aperture this variation is non linear for both coherent and incoherent illumination. For truncated apertures, peak intensity ratio is more sensitive to the intensity ratio in the presence of coherent conditions.

IV. Conclusion

Intensity distribution of various apertures were studied in this paper. Resolution ability of optical system concluded based dip point between two principle maxima and the intensity of 1st side lobe either sides of maximas. Optical imaging system with circular aperture well resolved the two point objects in the case of free of aberration as compared with truncated apertures, but in the presence of full of defocus and spherical aberration resolution is worsted. The truncation of circular aperture suppressing the side lobes and increasing the dip between two peaks as increasing intensity ratio. magnitude of rate of change of peak intensity ratio is more in the truncated aperture 0.8. From all these observations we can conclude that two point resolution of an optical imaging system with truncated aperture is more as compared with circular aperture in the presence of full of defocus and spherical aberration for both coherent and incoherent illumination .

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