

Research Paper

INTENSITY VARIATIONS IN PARTIAL APODIZED DEFOCUS

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Abstract: Intensity variations in partially apodized defocused optical systems are characterized by redistribution of energy in spread function where apodizer suppresses side lobes while generally decreasing the central peak intensity. In the presence of defocus, apodization controls the trade-off between the central peak sharpness and the intensity of the surrounding rings. The study of ability of making difference in arbitrary shapes and orientations is important for evaluating image equality for complex optical systems. Investigations have been made on the imaging properties of defocused optical systems also on the imaging characteristics of the optical systems suffering from defect-of-focus made. The locations of first, second and third minimum, positions and intensities of the central maximum and various optical side-lobes have been studied for apertures with shading and shaping of apertures. The optical system, which is free from aberrations, is called perfect optical system. In practice, optical systems are neither ideal nor perfect. Therefore, they come under real optical systems. In real optical systems, the image of a line object is not itself a line. The theory of image formation where the response to signals with complex geometries is a necessity along with not fully characterized coherent function. Hence, an ideal optical system gives a point image of a point object and straight-line image of a straight line. That means the image and objects should be in a projective relation to each other. In the present study, investigations have been carried out on the intensity distribution of the two-line objects in the image plane by defocused optical system having an apodised circular aperture and described the effects of defocusing and aberration parameters on it.

Key words: aberration, aperture, apodizer, defocus, optical system etc

1.1 INTRODUCTION:

An exact knowledge of the diffraction pattern intensity distributions of stationary apertures in the presence of aberrations is a pre-requisite for further analysis towards the final goal. The goal will be to exploit the conditions that lead to image formation. It means, a detailed knowledge of the distribution of the light illumination at and near the focus of an optical system is highly desirable to give acceptable interpretation for the results obtained by the aberrated optical imaging systems consisting with the aid of large number of components.

The importance of this subject was first recognized and studied by Airy in the year 1834 and subsequently Lord Rayleigh has investigated the light distribution in the discs in the presence of spherical aberration and evaluated the central intensity (BUXTON, 1921). LOMMEL (1885) has been developed the mathematical theory for the light distribution at and near the focus of an optical system by employing a circular aperture and it was verified experimentally. He has studied in detail the light distribution in the images of monochromatic point sources situated in the out of focus planes.

Almost at the same period of time, a similar but a less comprehensive analysis of the intensity distributions near the edge of the geometrical shadow relating to the circular aperture was published by STRUVE (1886). SCHWARZSCHILD (1898) had also contributed his work to this subject by studying the light intensity distribution for points far away from the focus.

1.2 MATHEMATICAL FORMULATION:

The Hanning amplitude filter that was used as a pupil function or the amplitude transmittance $f(r)$ to apodise the rotationally symmetric optical imaging system is given by

$$f(r) = \text{Cos}(\pi \beta r) \quad (2.1)$$

where β is the apodisation parameter which controls the degree of the non-uniform transmission of the exit pupil and r is the normalized distance of the point on the pupil from the center. Both β

and r vary from 0 to 1.0. $\beta=0$ specifies the free aperture or Airy type of pupil. The expression for the amplitude PSF for the Hanning amplitude aperture is obtained from the equation.

$$G_F(\phi_d, \varphi_s, Z) = 2 \int_0^1 \cos(\pi\beta r) \exp\left[-i\left(\phi_d \frac{r^2}{2} + \frac{1}{4}\varphi_s r^4\right)\right] J_0(Zr) r dr \quad (2.2)$$

For the Gaussian focal plane, $\phi_d = 0$. Hence the above expression becomes

$$G_F(0, \varphi_s, Z) = 2 \int_0^1 \cos(\pi\beta r) \exp\left(-i\frac{1}{4}\varphi_s r^4\right) J_0(Zr) r dr \quad (2.3)$$

In the absence of the primary spherical aberration the amplitude PSF (2.2) is given by

$$G_F(\phi_d, 0, Z) = 2 \int_0^1 \cos(\pi\beta r) \exp\left[-i\left(\phi_d \frac{r^2}{2}\right)\right] J_0(Zr) r dr$$

For annular apertures the lower limit is not zero but some non-zero value.

$$G_F(\phi_d, 0, Z) = 2 \int_{\varepsilon}^1 \cos(\pi\beta r) \exp\left[-i\left(\phi_d \frac{r^2}{2}\right)\right] J_0(Zr) r dr$$

In general, the expression for amplitude point spread function of the optical system suffering from defect of focus and primary spherical aberration can be written as

$$G_F(\phi_d, \varphi_s, Z) = 2 \int_{\varepsilon}^1 f(r) \exp\left[-i\left(\phi_d \frac{r^2}{2} + \frac{1}{4}\varphi_s r^4\right)\right] J_0(Zr) r dr \quad (2.4)$$

Where $f(r)$ is the amplitude filter. In the present study the following filters are employed:

$$f(1) = \cos(\pi\beta r)$$

$$f(2) = \frac{\sin(\pi\beta r)}{(\pi\beta r)}$$

$$f(3) = 1 - \beta r^2$$

$$f(4) = 1 - \beta r$$

The above expressions give the complex amplitude PSF of an aberrated and apodised optical system. The intensity or irradiance PSF $B_F(\phi_d, \varphi_s, Z)$ is given by the squared modulus of the amplitude PSF.

$$B_F(\phi_d, \varphi_s, Z) = |G_F(\phi_d, \varphi_s, Z)|^2 \quad (2.5)$$

Accordingly, the intensity PSF in the Gaussian focal plane is given by,

$$B_F(0, \varphi_s, Z) = |G_F(0, \varphi_s, Z)|^2 \quad (2.6)$$

In the defocused and aberration free plane the intensity PSF is

$$B_F(\phi_d, 0, Z) = |G_F(\phi_d, 0, Z)|^2 \quad (2.7)$$

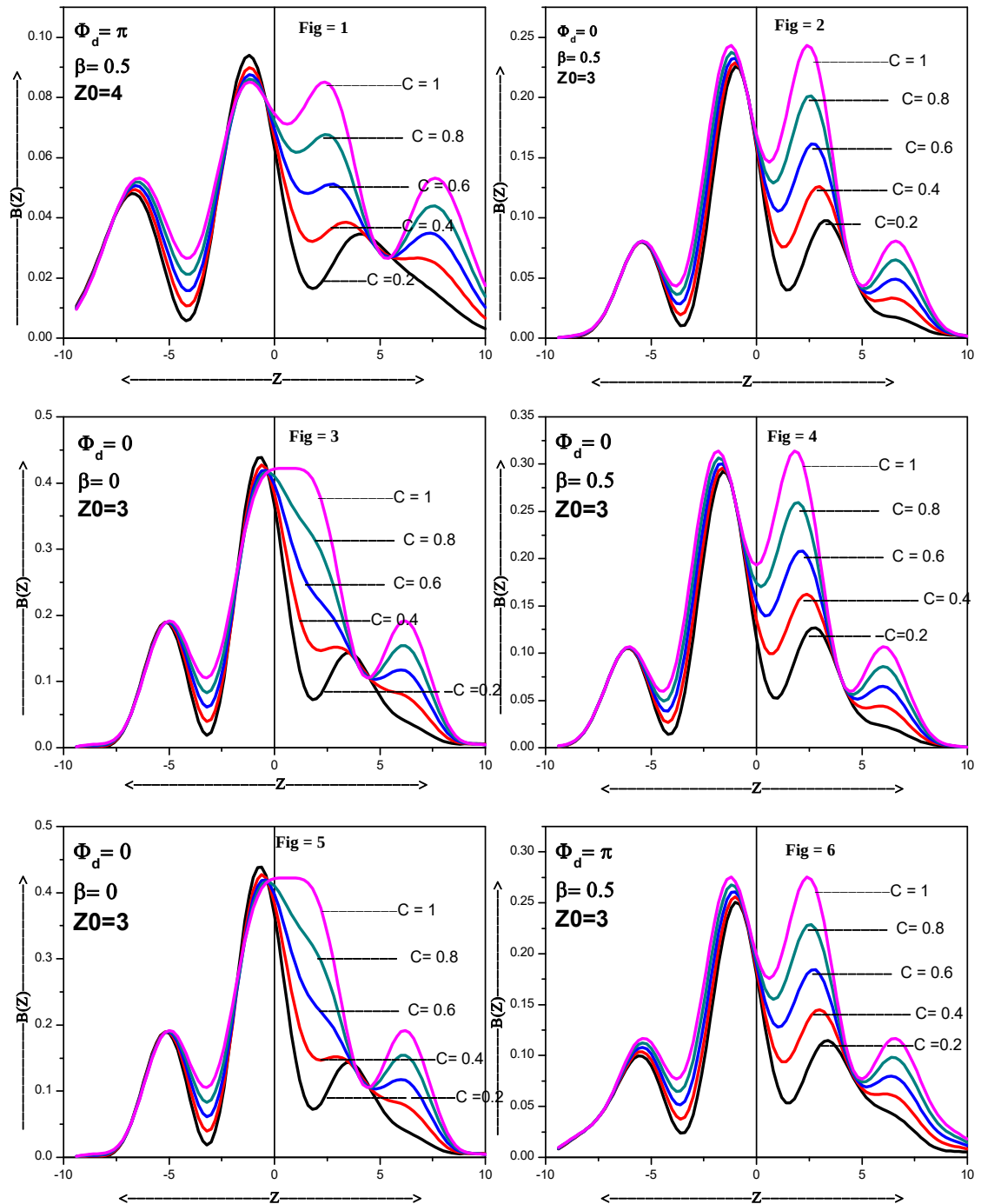
For a clear aperture or for a perfect lens, $f(r) = 1$. The expression for the normalized intensity at a specified point in the Gaussian focal plane becomes,

$$I = \left[\frac{2J_1(Z)}{Z} \right]^2 \quad (2.8)$$

1.3 RESULTS AND DISCUSSIONS:

In The present investigations the intensity of partial defocus Spread Function has been computed, using the above expressions for circular apertures, by means of employing Matlab-25 version to study the effects of apodisation and defect of focus on the performance of optical imaging systems. The apodisation parameter (β) is varied from 0 to 1 in steps of 0.25. Here, $\varepsilon = 0$ represents circular aperture whereas, $\varepsilon \neq 0$, gives the annular aperture.

The influence of defect of focus (ϕ_d) on the optical system aberrated is studied analytically for various degrees of apodisation. For the intensity variations for $C = 0.2$ to 1 in the increments of 0.2 the figures 1 and 2 the resolution of the partially apodised optical systems the resolutions for the intensity variations were very clear and with the figure 3 the resolutions were changed, when $\phi_d = 0$ for the figures 3 to 5 at the partial apodization this happened due to the increase in the $\phi_d = 0$ to $\phi_d = \pi$ this we can observe in the figure 6.



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