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Studies on Two Line Resolution with 2π Defocus

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Abstract

Rotationally symmetric optical imaging systems have been considered which means that, the diffraction effects along with aberrations limit the performance of the optical systems. A rotationally symmetric optical system is that system, which has the same properties on the circumference of any circle and whose center lies on the symmetry axis of the system. Further it is also assumed that the optical system is isoplanatic (the imaging properties do not change over a certain distance in the image plane) where, if the object point changes in its location, the image point changes only in its location but not in functional form. The diffracted field characteristics have been studied for circular apertures in the presence of defocus under the influence of intensity variation to assess the performance of the optical imaging systems. Throughout this work rotationally symmetric optical imaging systems have been considered which means that, the diffraction effects along with aberrations limit the performance of the optical systems.

Keywords
Aberration, isoplanatic, diffraction, symmetry and spectroscopy etc

1. Introduction

(LIPSON, 1972) The image formation was due to the resultant of the double-diffraction process has been directly propounded by Zernike. PORTER (1906) has described Abbe's theory of image formation in terms of Fourier series. Earlier, it was thought that Abbe's analysis could be applicable only to coherent imagery. (MARTIN, 1966; RAYLEIGH, 1896) In 1896, however, Lord Rayleigh has proved that same forms of analysis could be applied to incoherent imagery.

(GOODMAN, 1968) The fields of optics and communication share in common the properties of "linearity" and "invariance" and the mathematics of Fourier transforms. Fourier transform translates the principle of Huygens and enables the study of diffraction phenomenon. It translates the formation of images of extended objects and brings in the notion of transfer function. It describes the degree of spatial coherence in terms of source spectrum. In the domain of interference spectroscopy, it relates the intensity distribution in the interferogram to the spectral distribution of source energy. (AMI CHANDRA and SINGH, 1982) To characterize the shape of a point object, the diffraction pattern sampling can be used since the object and its Fraunhoffer diffraction pattern form a pair of Fourier transform under certain circumstances.

2. Mathematical Formulation

For Defocus Aberration the parameter $\{\phi_d = 2\pi\}$ is used for the intensity of the two Line Resolution in the case of Circular Apertures for the apodised filter $\{\cos(\pi\beta r)\}$.

$$B(Z) = \left| 2\int_0^1 \cos(\pi\beta r)\cos[2\pi(Z+Z_0)x] e^{-i\left(\phi_d \frac{x^2}{2}\right)} dx + 2c\int_0^1 \cos(\pi\beta r)\cos[2\pi(Z-Z_0)x] e^{-i\left(\phi_d \frac{x^2}{2}\right)} dx \right|^2$$

GASKILL (1978) The object complex amplitude transmission of two such opaque straight edges displaced form the origin by 'u_0' dimensionless diffraction units is given by GASKILL as

$$A_1\left[(u-u_0), v'\right] = 1 \quad ; u < u_0$$
$$= 0 \quad ; u \geq u_0 \qquad \text{------------- (1)}$$

$$A_1\left[(u+u_0), v'\right] = 1 \quad ; u < -u_0$$
$$= 0 \quad ; u \geq -u_0 \qquad \text{------------- (2)}$$

Following Fourier analytical methods and the coherent image formation scheme, applied to an opaque straight edge the image amplitudes is given by

$$A'(Z) = \frac{1}{2} + \frac{1}{\pi}\int_0^1 f(x)\frac{\{Sin(zx)\}}{x}dx \qquad \text{------------- (3)}$$

Where $Z = 2\pi u_0$

The image amplitudes of equation (3) can be derived similarly as,

$$A'_1(u' - u_0, v') = \frac{1}{2} + \frac{1}{\pi}\int_0^1 f(x)\frac{Sin\{2\pi(u' - u_0)x\}}{\{2\pi(u' - u_0)x\}}dx \qquad \text{------------- (4)}$$

And

$$A'_2(u' + u_0, v') = \frac{1}{2} + \frac{1}{\pi}\int_0^1 f(x)\frac{Sin\{2\pi(u' + u_0)x\}}{\{2\pi(u' + u_0)x\}}dx \qquad \text{------------- (5)}$$

Where $A'_1(u' - u_0, v')$ and $A'_2(u' + u_0, v')$ are the image amplitude distributions of the complex object amplitude transmissions $A_1(u' - u_0, v')$ and $A_2(u' + u_0, v')$ respectively.

$$A'_{L1}\left(u'-u_0,v'\right)=\frac{d}{dx}\left\{A'_1\left(u'-u_0,v'\right)\right\}$$ ------------- (6)

$$A'_{L2}\left(u'+u_0,v'\right)=\frac{d}{dx}\left\{A'_2\left(u'+u_0,v'\right)\right\}$$ ------------- (7)

If the amplitude of transmission in one of the lines viz; (6) can be controlled by a parameter 'c' equal to unity for maximum amplitude in the image then the amplitude in the image of such a line of variable amplitude is given as

$$A'_{L1}\left(u'-u_0,v'\right)=c\,\frac{d}{dx}\left\{A'_1\left(u'-u_0,v'\right)\right\}$$ ------------- (8)

$$A'_{L2}\left(u'+u_0,v'\right)=\frac{d}{dx}\left\{A'_2\left(u'+u_0,v'\right)\right\}$$ ------------- (9)

Where c = 0.2, 0.4, 0.6, 0.8 and 1.0 can be termed as the intensity ratio of the two lines. The superposition of these edge gradients results in the amplitude response of two lines is given. After making some mathematical simplification we get,

$$A'_{LL}\left(u',v'\right)=2\int_0^1 f(r)Cos\left\{2\pi\left(u'+u_0\right)r\right\}dr+2c\int_0^1 f(r)Cos\left\{2\pi\left(u'-u_0\right)r\right\}dr$$ ------------- (10)

Where $A'_{LL}\left(u',v'\right)$ is the amplitude response of two-lines

The squared modulus of equation (10) results in the intensity distribution $B'_{LL}\left(u',v'\right)$ in the image of the two-lines. Thus

$$B'_{LL}\left(u',v'\right)=\left|2\int_0^1 f(r)Cos\left\{2\pi\left(u'+u_0\right)r\right\}dr+2c\int_0^1 f(r)Cos\left\{2\pi\left(u'-u_0\right)r\right\}dr\right|^2$$

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

$$f(r_1)=\cos(\pi\beta r)$$

$$f(r_2)=1-\beta r$$

$$f(r_3)=1-\beta r^2$$

$$f(r_4)=\sin\frac{(\pi\beta r)}{(\pi\beta r)}$$

3. Graphs

Graphs are presented in Figure 1.

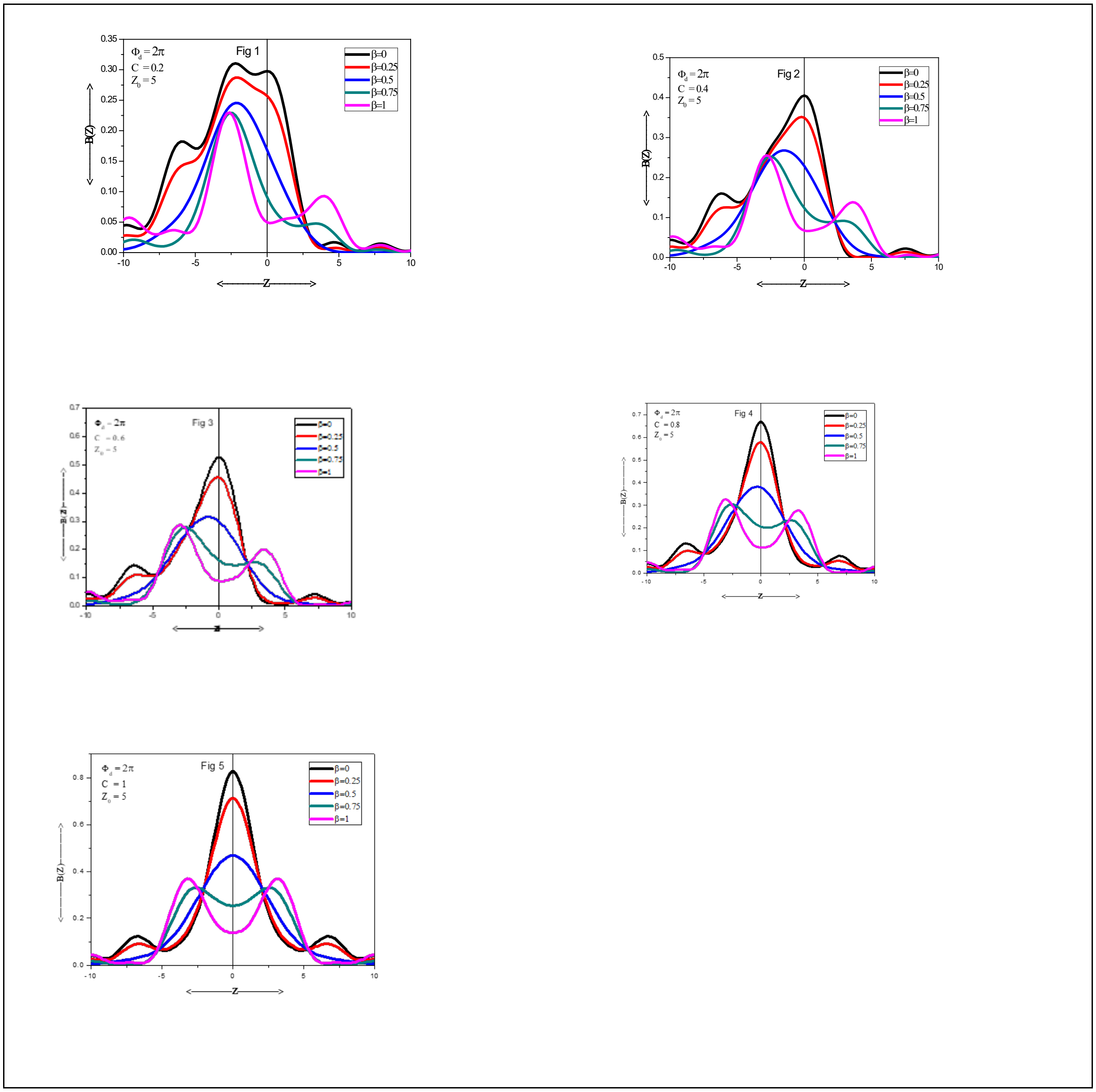

Figure 1. Intensity distribution curves

4. Results and Discussions

It is depicted clearly in Figure 1. With increase of degree of amplitude apodization in the central region of the aperture, the central disc widens; more energy is accumulated in the central region compared to the energy-concentrated in the near vicinity of the diffraction centre, whereas in the case of asymmetric apodization the energy is shifting to one side of the diffraction and simultaneously narrowing the central lobe of the diffraction pattern. The side on which the optical lobes are suppressed is termed as good side and the energy from this side has been excluded more to the outer rings. For the distance of separation of Two Line $Z_0 = 5$ different peaks are drawn. The intensity ratios are increased from C = 0.2 to 1 with the incrementation of 0.2 keeping the all parameters are kept constant. For the apodisation parameter β = 1 the two peaks between the center line are varied and it is exact in the case of a fFgure 5. When the apodisation is null i.e., β = 0 there is no dip in the figures from 2 to 5. When it is at high degree of apodisation β = 1 we can observe a clear resolution which is increasing on both sides of the center line upto the Figure 1.

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