Two Line Resolution of apodised optical system with circular apertures in the presence of Primary Spherical aberration, Defocusing and Coma

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Abstract— **Several attempts have been made to obtain the homo-centricity in the direction of minimizing the aberrations by assigning different values to the constructional parameters of the lens systems, resulting in the design of several refined optical systems. Even though a great deal of success was obtained in two line resolution of optical system, in certain regions the simple geometrical treatment of the aperture found to be inadequate. So applying the primary spherical aberration, coma and defocus aberration to the optical system In particular, it was observed that deviations from this treatment must be expected in the immediate neighborhood of the boundaries i.e., shading of the apertures in the regions where a large number of rays meet**

I. INTRODUCTION

J. B. Joseph Fourier laid the foundation of modern optical processing by proposing what is now known as 'Fourier theory'. His theory is a basic mathematical tool that we shall use very often to explain many optical phenomena (LIPSON and LIPSON, 1969). The importance of this theory is that it is applicable to both periodic and non-periodic functions; also, it leads to a much better understanding of the formation of optical images in various situations like coherent, incoherent, or partially coherent illumination.

apodisation is the technique that modifies the imaging properties of an optical system by manipulating its entrance pupil. It is one aspect of the wide range technique of spatial filtering (HECHT and ZAJAC, 1987). Apodisation is similar to pulse shaping in electrical engineering (PAPOULIS, 1968). Apodisation may be defined as the deliberate modification of the pupil function so as to improve some measure of the image quality (WETHERELL, 1980). Straubel may be considered as the founder of apodisation theory (BARAKAT, 1962). A complete or partial suppression of the side-lobes at the cost of enlarging the central part of the diffraction pattern by modification of the entrance pupil of an optical device is known as apodisation. The resolving power of the system for point objects of equal brightness is diminished by apodisation (JACQUINOT and ROIZEN-DOSSIER, 1964)

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II. THEORY

Considering the straight edge as the basic mathematical building block, the image amplitudes of two opaque straight edges shifted by 'u_o'' dimensionless diffraction units on the either side of the origin in the object plane will result in the image amplitude of two opaque straight edges in the image plane of the optical system

The gradient of the edge response function (ERF) with respect to u' will result in the amplitude $A_{L1}'(u'-u_o, v')$ and $A_{L2}'(u'+u_o, v')$ in the images of two lines [HOPKINS and ZALAR ,1987] resulting in a combination of two line spread functions given by a separation 'u_o'' respectively.

$$A_{L1}'(u'-u_o, v') = \frac{d}{dx}[A_1'(u'-u_o, v')]$$

$$A_{L2}'(u'+u_o, v') = \frac{d}{dx}[A_2'(u'+u_o, v')]$$

If the amplitude of transmission in one of the lines can be controlled by a parameter unity for maximum amplitude in the image then the amplitude in the image of such a line of variable amplitude is given as

$$A_{L1}'(u'-u_o, v') = \alpha \frac{d}{dx}[A_1'(u'-u_o, v')]$$

$$A_{L2}'(u'+u_o, v') = \frac{d}{dx}[A_2'(u'+u_o, v')]$$

Where α = 1.0, 0.75, 0.50, 0.25 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 given after simplification as

$$A_{LL}'(u', v') = 2\int_0^{+1}\frac{(1+C\cos(\pi x2))}{(1+C)}\cos\{2\pi(u'+uo)x\}\,dx + 2\alpha\int_0^{+1}\frac{(1+C\cos(\pi x2))}{(1+C)}\cos\{2\pi(u' \; uo)x\}\,dx$$

Where $A_{LL}'(u', v')$ is the amplitude response of two lines.

The squared modulus of will result in the intensity distribution $B_{LL}'(u', v')$ in the image of the two lines.

$$B_{LL}'(u', v') = \left| 2\int_0^{+1}\frac{(1+C\cos(\pi x2))}{(1+C)}\cos\{2\pi(u'+uo)x\}\,dx + 2\alpha\int_0^{+1}\frac{(1+C\cos(\pi x2))}{(1+C)}\cos\{2\pi(u'-uo)x\}\,dx \right|^2$$

III. RESULTS AND DISCUSSION

The intensities in the Gaussian image peaks increases with increase in the separation until the two lines are resolved in the Rayleigh sense i.e. until the contrast at the saddle point drops to 26.5% of the maximum intensity, while the central intensity goes from a maximum value at lower separations to a minimum value and then raises again decreasing the value of the Gaussian intensity peak.

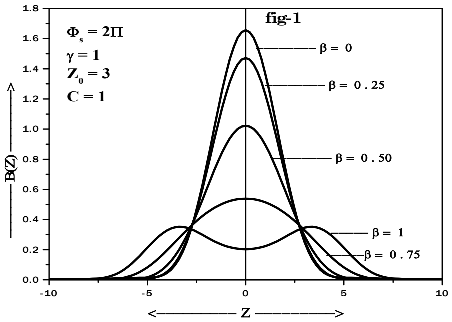
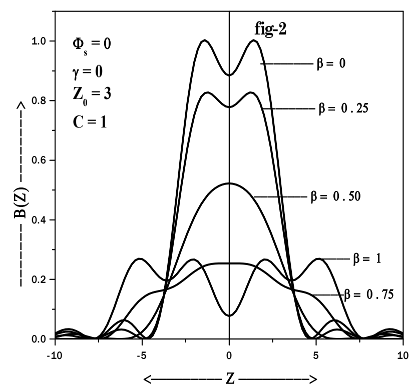
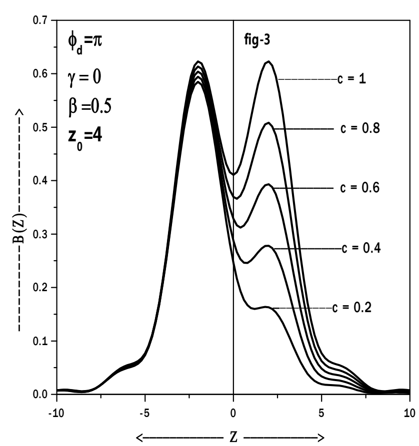
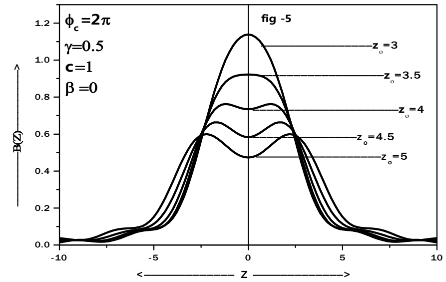
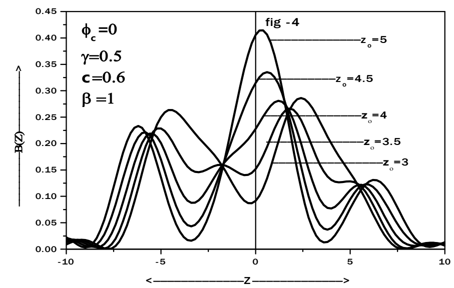


Fig -1 depicts the intensity distribution curves for two line objects in the image plane for circular aperture apodised with Hanning amplitude Filter. When the Optical imaging system is suffering from high degree of primary spherical aberration for two equally bright line object placed under coherent illumination. As the apodisation parameter is increased for higher values of apodisation, $\beta = 1$, there appears a clear resolution between the two lines when they are separated by a distance of Z0 = 3 the chosen filter is effective in resolving the two lines for high









in fig-2 the apodisation is varied from 0 to 1 by the increment 0.25 . when the optical system is free for spherical aberration we get the resolution for high apodisation and also for no apodisation and we get no resolution for the partial apodisation and the intensity ratio is kept at c=1 and when the optical system is under completely in coherence for the chosen filter $\sin(\pi\beta r)/(\pi\beta r)$.

In fig -3 it depicts the optical system is suffering with defocusing aberration when the defocusing parameter is at $\varphi_d = \pi$ and the two bright lines are at a distance $Z_0 = 4$ and when the optical system is under partial apodisation and also under complete incoherence. The intensity variations varied from 0 to 1 by increasing value of 0.2 and resolution is started at c=0.4 to c=0.8 and at c=1the two lines are best resolved for chosen filter

In coma the fig4 and fig 5 depicts the two bright lines are kept at partial incoherence $\gamma = 0.5$ and at the high apodisation $\beta = 1$ and the resolution of the lines are better and their intensities are at the level 0.6 and when the coma aberration is free the two line resolution is started at $Z_0 = 3$ to $Z_0 = 3.5$ and for the chosen filter $\sin(\pi\beta r)/(\pi\beta r)$. And in fig -5 when the apodisation free and the two lines are kept at partial incoherence and the coma aberration for the optical system is given as the distance between the two bright lines vary only at $Z_0 = 4$, $Z_0 = 4.5$ & $Z_0 = 5$. It depicts the resolution criterion has been well resolved when the intensity ratio is kept at C = 1 for the coma aberration is fully maximum $\varphi_c = 2\pi$ for the chosen filter $\sin(\pi\beta r)/(\pi\beta r)$. And for the given circular aperture they are best resolved.

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