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Intensity Analysis for Optical System Apodized with Hanning Amplitude Filter

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Abstract:

In this paper, studied the aberrated image quality of incoherently illuminated point object in the presence of apodization. Half width at half maximum (HWHM) of an apodized intensity has been investigated by introducing pupil function. The analytical studies were made for annular pupil apodized with Hanning amplitude filter under the influence of defocus and primary spherical aberrations. Aperture obscuration effect and apodization on (HWHM) with the peak intensity was considered.

Keywords: imaging systems, Coherence, Aberrations, pointobjects.

Introduction

The goal of lens designers is to determine the efficiency of the lens which represents the accuracy of optical design by determining the image quality. The number of factors that have an important impact on the evaluation of the image quality of the imaging system [1]. One of these factors is the wavefront aberration: coma, spherical aberration, field curvature, astigmatism which is inherent in optical systems although defects in manufacturing or alignment, as well as ergonomics, can cause additional aberration. The defocus effect causes to move longitudinally from the projected Gaussian point and propagate causes the defocus effect causes the focal point to move longitudinally from the projected Gaussian point and propagates the beam from the central maximum to the side lobes. To correct lens defects as well as a spherical aberration or in other words, Control of aberration is mostly achieved by employing filters [2]. The Amplitude filter reduces aberrations, but at the expense of the light transmitted by the optical system [3]. The second factor is the determination of the distribution of the intensity in the image plane (PSF) since most of the optical functions can be considered as being derived from it by a differential or integrally relationship [4]. PSF is a description of the distribution of intensity at the image plane of a point object, linear or sharp edge. Intensity distribution depends on the diffraction generated by the aperture and the type and amount of aberration in the lens. So it's often a combination of multiple optical effects, including diffraction, aberration, defocus, veiling glare, and etc. Strehl ratio [5] was the parameter most often used to estimate the distribution of energy along the axis of optical to quality evaluate PSF near the focal plane. Hence,[21-41] studying the imaging properties of the optical systems from the knowledge of the Intensity distribution has become an important method in designing and testing these systems. Apodization is a technique that is equivalent to the imaging optical system properties, many apodization filters have been proposed in instrumental optics for various purposes [6]. In our previous paper [7] optical properties investigated of apodized image system from the square aperture and show to achieve high Strehl ratio. In the present paper, the characteristics of an aberrated optical system with an annular pupil apodized by a Hanning amplitude filter have been studied in terms of the width of the central maximum to achieve good resolution. Half-width at half-maximum (HWHM) [8] becomes an important image assessment criterions to discuss the distribution of intensity in the imaging plane, and it has been evaluated distance at the diffraction center is 50% of the peak intensity of the main peak.

Related work

When size and shape of aperture affect; the structure of an image, several authors have studied a variety of methods to modify the pupil of the entrance to improve image quality. Andra and Sagar [9]. Obtained improved axial resolution and evaluated HWHM for apodised optical systems using two dimensional complex pupil filters. Devi etal [10] have derived an expression of Point spread function for optical system apodised with Gaussian filter,the computed result is done for various cases of apodised parameter.
Reddy [11] studied the central intensity for annular aperture in which the Peripheral is clear and the central part is apodized with a pair of complimentary filters. Narsaiah et al [12] studied the influence of the filter to estimate the optimum value of apodisation for annular aperture in aim of realizing the least possible radius for the first dark ring which in turn influences the resolving aspects of the optical imaging systems. Campos et al [13] studied the effect of different types of amplitude, complex and phase filters on to the axial and transverse behavior of an optical system, and they attempt to control the amplitude and phase in LC-SLM in order to be able to carry out a pupil filter. Venkanna et al [14] determined the point spread function of aberrated optical system apodized Lanczos at Hanning, amplitude filters for rotationally symmetric coherent optical system.

Mathematical formula

In waves of diffraction theory, the pulse amplitude in response to the optical imaging system for spherical aberration is the "Fourier transform" of pupil mask function is symmetrical, which consists of the permeability of the regular capacity. In this study, we considered a generalized Hanning amplitude filter [15], with which the pupil function can be expressed:
τ (*r*) □□*Cos* □□□□□□□ (1)
□: controlling of apodizing parameter the transmission of non-uniform for the pupil.
β=0 corresponds to the Airy case based on the diffraction theory; the amplitude spectrum is the Fourier transform of pupil function [16].

$$A(u,v) = \int_y \int_x f(x,y) \cdot e^{i2\pi(ux+vy)} dxdy \quad (2)$$

(u,v): Dimensionless diffraction coordinates in optical system receiver plane.

$$f(x,y) = \tau(x,y) \cdot e^{ikY(x,y)} \quad (3)$$

$k = \frac{2\pi}{\lambda}$: Wave number, and λ is incident radiation beam wavelength, notice that the pupil function is separable in Cartesian coordinates:

$$Y(x, y) = Y_D (x^2+y^2) + Y_S (x^2+y^2)^2 \quad (4)$$

Here, YD and YS are the out of focusing effect and the Control parameters in the main spherical aberration respectively [17, 18]. Now, the distribution of image intensity formed by the apodized visual system can obtain by the "square parameter" of expression [1].

$$\mathrm{I}\big((u,v)\big) = \big|A\big((u,v)\big)\big|^2 \quad (5)$$

Let z=2πu, m=2πv, for the given annular pupil then the expression (4) becomes:

$$I(z) = F\left| \int_{-1}^{1} \int_{-\sqrt{1-y^2}}^{\sqrt{1-y^2}} (\delta + \beta(x^2+y^2))^N \, e^{izx} \, dxdy \right|^2 \quad (6)$$

$$I(z,m) = N \left| \int_{-1}^{1} \int_{-\sqrt{1-y^2}}^{\sqrt{1-y^2}} \tau(x,y) \, e^{iky(x,y)} \, e^{i(zx+my)} \, dxdy - \int_{-\varepsilon}^{\varepsilon} \int_{-\sqrt{\epsilon^2-y^2}}^{\sqrt{\epsilon^2-y^2}} \tau(x',y') \, e^{iky(x')} \, e^{i(z'x'+m'y')} \, dx'dy' \right|^2 \quad (7)$$

0≤ ε<1: Acentral obstacle parameter (ratio of inner circle "central obstacle" to the radius of outer circle (aperture).
x, y: Pupil plane coordinates and (x',y') coordinates at obscuration plane, and N is normalizing constant. So the intensity distribution I (z) symmetric on (z, m) axes, then one coordinates is sufficient can be reduced to only one axis, at m=0, and equ.(5) can written by:

$$I(z) = N\left| \int_{-1}^{1} \int_{-\sqrt{1-y^2}}^{\sqrt{1-y^2}} \cos(\pi\beta r) \, e^{iky(x)} \, e^{i(zx)} \, dxdy - \int_{-\varepsilon}^{\varepsilon} \int_{-\sqrt{\epsilon^2-y^2}}^{\sqrt{\epsilon^2-y^2}} \cos(\pi\beta r) \, e^{iky(x\prime)} \, e^{i(z\prime x\prime)} \, dx'dy' \right|^2 \quad (8)$$

Investigations of the effects of the diffraction coefficient, aberrations, and opacity on point objects images composed of non-coherent optical systems encoded by a Haning filter using expressions (7) were evaluated using MATHCAD. I (z) was obtained in point objects images for different values of diffraction variable (z) ranging from 0 - 7. The aperture considered central obscuration parameter of are ε=0, 0.25, 0.5, and 0.75, but at ε=0 denotes a circular aperture. To achieve the optimum image quality in the case of spherical aberration, we balance it with defocus. One approach derived by Marechal [19] is to minimize the mean square deviation of the wave front to maximize the intensity PSF corresponding to Strhel Ratio W_{20}=-W_{40} [20].

Results and Discussion

To calculate an energy distribution of apodized pupil for the various values using eq. (6) of central obscuration parameter ε. From figures 1(a), (b) and (c) the intensity distribution curves as distance function of image center for various amount of the Hanning amplitude apodization parameter for annular aperture (ε=0.25,0.5,0.75) respectively . It is clear that the intensity decrease with the degree of apodization. If the pupil filter becomes Airy ($\beta = 0$, $W_{20}=0$) intensity possess maximum value, and for various amount of apodization parameter intensity, PSF is gradually decreased.

Figures (2) and (3) depict the intensity distribution profiles for central obscuration parameter ε=0.5 when the optical system is under extreme influence of focus defect and primary spherical aberration. From the profile of curves of intensity distribution it is was evident that the intensity decreasing with the increased defocusing and primary spherical aberration, but there is a clear reduction of the HWHM (where the intensity becomes half of the central maximum) which is narrowed down with respect to the different values of the apodization parameter β.

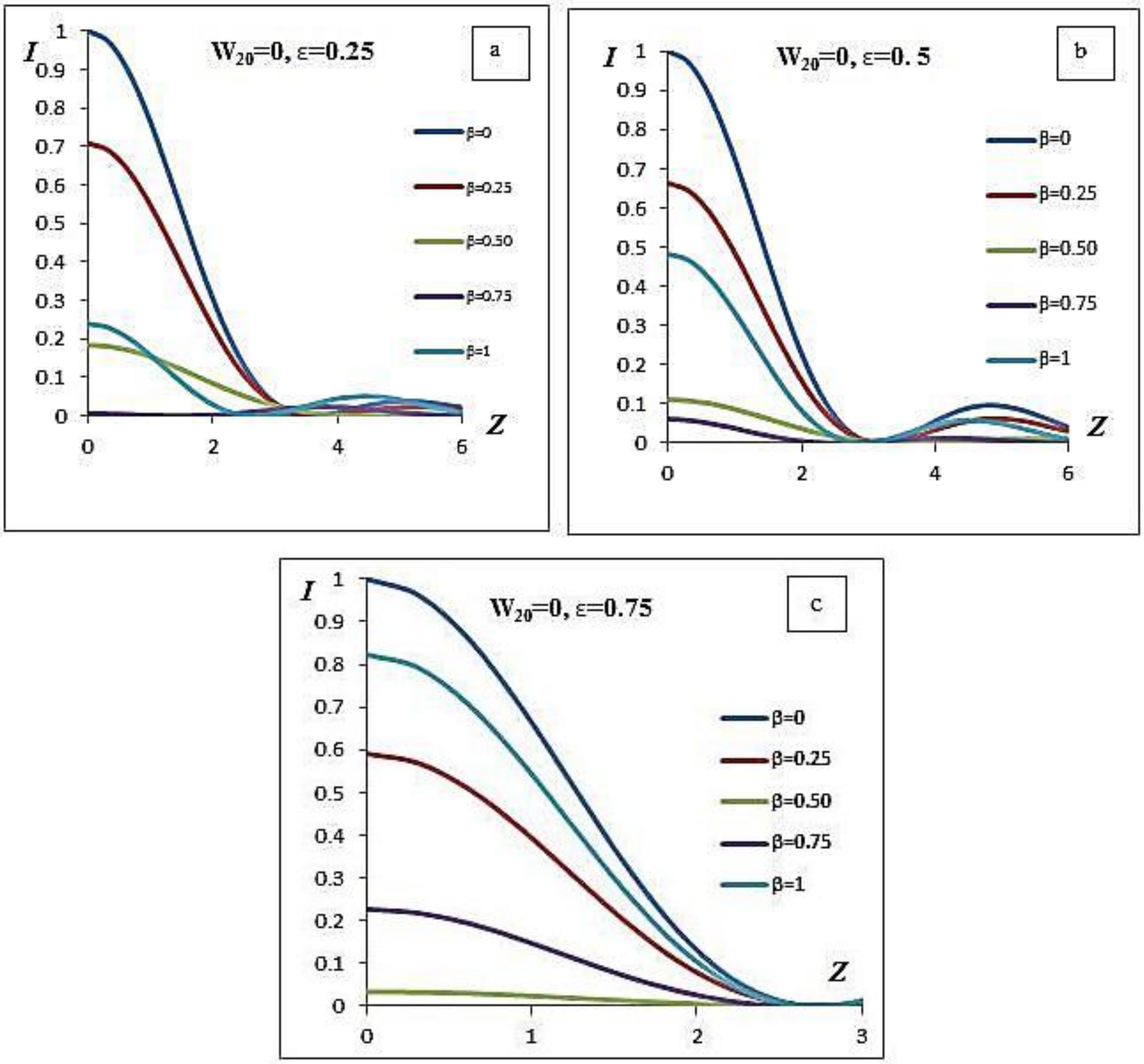

Figure (1): Intensity distribution with various amount of apodization parameter (□).

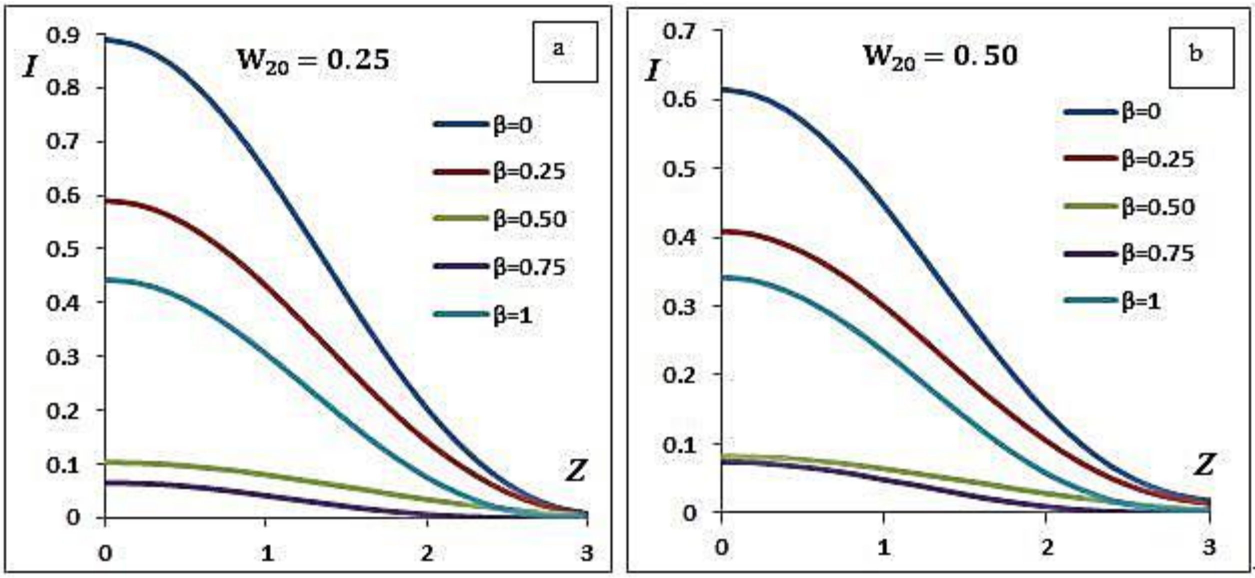

Figure (2): Intensity distribution for apodization parameter β different values with defocus.

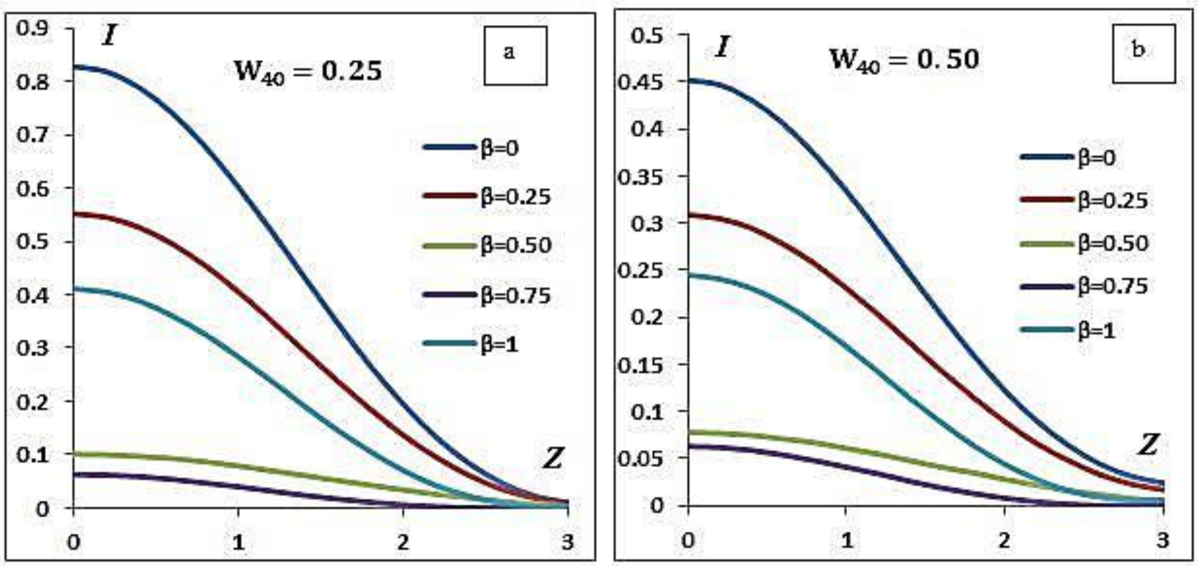

Figure (3): Intensity distribution for apodization parameter β different values with aberration

It's found from Figure (4) that when the spherical aberration balanced with defect of focus $W_{20}= -W_{40}$ in order to minimize its variance, the maximum intensity increase and for different amount of the parameter of apodization HWHM is become narrow.

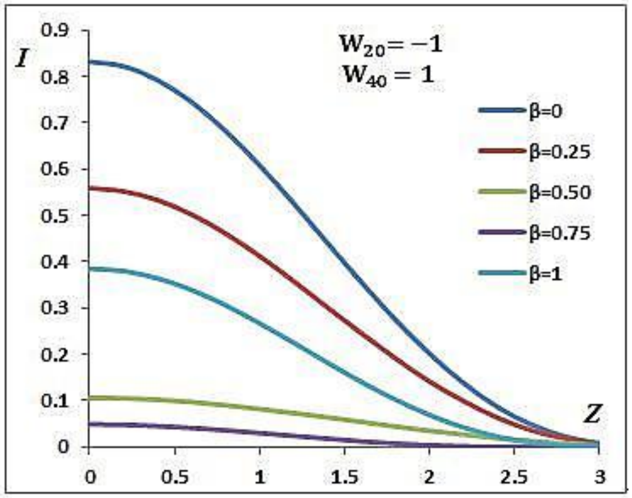

Figure (4): Optimum balanced intensity for apodization parameter β different values.

Conclusions

The purpose of this investigation to improved resolution with half of the maximum intensity studies profile which has been derived and computed by considering Hanning pupil filter. Pupil apodization efficiency of under a primary spherical wave aberrations and the defocus influence depends greatly on β and Y values.

The numerical values are computed for the various values of apodization parameter. The apodization degree very effective on the central maximum width, it's found that the best image quality criterion HWHM can be obtained at apodization parameter β=0.25.The intensity obtained lower values with the degree of apodisation, if pupil filter becomes Airy (β =0, $Y=0$) the intensity possess maximum value (equal to 1). HWHM is narrower than that of airy case at the presence of defocus and spherical aberration and broadened with increasing Y, also cost decreasing irradiance, by balanced aberration coefficients we overcame limitations to improve accuracy.

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