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Performance analysis of optical imaging systems based on the fractional Fourier transform

SERGIO GRANIERI*, ENRIQUE E. SICRE
Centro de Investigaciones Opticas (CIOp), PO Box 124, 1900 La Plata, Argentina

and WALTER D. FURLAN
Departamento de Optica, Universidad de Valencia, 46100 Burjassot, Spain

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Abstract. Some image quality parameters, such as the Strehl ratio and the optical transfer function, are analysed in the generalized phase-space, or x-p domain, of the fractional Fourier transform associated with a modified one-dimensional pupil function. Some experimental results together with computer simulations are performed which illustrate the tolerance to defocus of different apertures.

1. Introduction

There are several criteria for analysing the performance of an optical imaging system for aberrations and/or focus errors. Among them we mention: Rayleigh's criterion [1], Maréchal's treatment of tolerance [2] and the Strehl ratio [3]. In these approachs, the on-axis image intensity is the relevant quantity. However, as Hopkins has suggested [4, 5], the analysis of Maréchal can be reformulated in order to give a tolerance criterion based on the behaviour of the optical transfer function (spatial frequency information) instead of the point-spread function (space information). More recently, some papers were published in which the Wigner distribution function (WDF) or the ambiguity function (AF) are employed to evaluate image quality parameters [6–12]. This point of view equally emphasizes both the spatial and the spectral information contents of the diffracted wavefields that propagate in the optical imaging systems.

On the other hand, the concept of the fractional Fourier transform (FRT) was introduced into optics by Mendlovic, Ozaktas and Lohmann [13–16]. From a viewpoint based on the WDF, since an ordinary Fourier transform results from a $\pi/2$ coordinate rotation of the input WDF, the FRT of order p can be achieved through a WDF phase-space rotation by an angle $\phi = p\pi/2$. Thus, the information content stored in the FRT changes from purely spatial to purely spectral as p varies from $p = 0$ to $p = 1$. By taking into account the link between the FRT formalism and the free-space diffraction [17–19], the imaging properties of a given

* Also Facultad de Ciencias Exactas, Universidad Nacional de La Plata, 1900 La Plata, Argentina.