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Abdallah Hamed

Speckle Imaging Using Aperture Modulation

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Dedications
To my parents and my wife

Preface

Even since the invention of lasers in 1960, there has been a renaissance in the field of optics and the field of optical electronics. Optical and optical electronics are now being applied in all branches of science and engineering. The famous book *Introduction to Fourier Optics and Holography* by Goodman (1968) and *Laser Speckle and Applications in Optics* by Francon (1978), followed by my recent publications on the subject led to the presentation of the book *Modulated Apertures and Resolution in Microscopy* by Hamed AM (2023) followed by the present book on *Speckle Imaging Using Aperture Modulation.* The content of the book extracted from my recent publications adds information on speckle imaging due to the modification that occurred in pupil distribution. This book is intended for graduate students in optical sciences.

The object of drafting a book on speckle imaging using pupils with different distributions is outlined below. When the circular aperture of uniform transmittance was replaced by modulated cracks the point spread function (PSF) changed, and the cutoff spatial frequency was changed leading to resolution improvement in the formed image using a fixed diffuser.

The book is composed of nine chapters about the formation of speckle images using modulated apertures and laser spectral Voigt distributions. In these chapters, we calculated the impulse response or the PSF corresponding to the apertures and hence obtained the resolution in the formed speckle images. The recognition of the direction of new apertures from elongated speckle images is outlined in Chap. 1. Speckle images using Gaussian and graded index apertures are investigated in Chap. 2. In addition, the contrast of the formed speckle images is outlined in Chaps. 3, 4, and 6. Among the investigated modulated apertures there is a Hamming linear distribution as described in Chap. 5 and others have concentric black and white hexagonal pupils as described in Chap. 7. The speckle images with irregular apertures are discussed in Chap. 8. Finally, in Chap. 9 we computed the intensity distribution for the new Hermit Gaussian annular aperture and plotted it for different transverse modes. Second, we calculated the speckle images corresponding to these apertures using the FFT technique which shows the dependence of the speckle pattern upon the beam nonuniformity.

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Contents

Chapter 1
Recognition of the Direction of New Apertures from Elongated Speckle Images

1.1 Introduction

Long elongated speckle images were obtained using mechanical scanning of the static speckle pattern [1]. The author presented a technique of spatially oriented speckle-screen encoding to improve the grating encoding technique for white-light image processing. Additionally, an artificial screen composed of small strips was photographed on a high-resolution film designed to obtain elongation ten times the average grain size of natural speckles [2]. In a recent publication by the author [3], numerical elliptical apertures of small elliptic shapes were analyzed and the Fourier transform was used to obtain speckle images of diffusers modulated by these elliptic apertures.

An approach for determining the roughness of engineering surfaces is the result of the speckle elongation effect. The laser speckle pattern, arising from light scattered from rough surfaces that are illuminated by polychromatic laser light, is detected in the far-field region. The incoherent superposition of these light intensities and angular dispersion cause speckle elongation [4]. This is characterized by increasing speckle widths and leads to a radial structure of the speckle patterns. With increasing surface roughness, the elongation is increasingly replaced by the decorrelation of the monochromatic speckle patterns for the different wavelengths. Such effects are detected with the CCD technique and analyzed by local autocorrelation functions of intensity fluctuations that are calculated for different areas of the speckle patterns. Hence, the autocorrelation method is applied to process laser speckle patterns. The relationships between the surface roughness and speckle elongation and between the correlation length of the autocorrelation function can be obtained. Consequently, a high surface roughness can be measured [5]. An oriented photographic diffuser is used to record an elongated speckle pattern. It was found that the contrast transfer when gratings were imaged through the slits in the diffuser was greater than that when imaging through a circular pinhole of comparable dimensions [6]. An autocorrelation algorithm for speckle size evaluation has been investigated [7–10]. The

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