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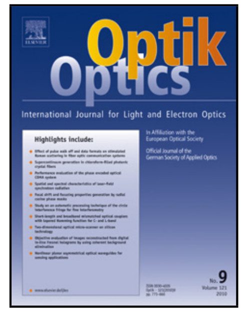

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Experimental study of the effects of the ratio of intensities of the reference and object waves on the performance of off-axis digital holography

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Abstract. In this paper we present an experimental study of the effects of the ratio of the intensities of the reference and object waves on the performance off-axis digital holography operating in tight diffraction-limited regimen. The analysis is focused on the comparison of the information contained in the hologram before and after performing the spatial filtering of the zero diffraction order and the twin image. We show that in the Fourier transform of the recorded hologram the information of the object is preserved regardless the ratio of intensities of the object and reference waves. This fact allows the right spatial filtering of the +1 or -1 diffraction order leading to similar reconstructed images for holograms recorded with very different ratios of the intensities of the reference and object waves. The results show that the usual rule of thumb of 1:1 ratio for seeking maximum fringe contrast is not really required. Experimental results of a regular die are utilized for validating the claims.

Keywords: Digital holography, digital image processing, image reconstruction techniques, intensity ratio, zero order of diffraction

1. Introduction

The numerical reconstruction of digitally recorded holograms, namely digital holography (DH), uses the two-step imaging method of optical holography proposed by D. Gabor [1]. Based on sharing the foundations of the optical holography, DH has been applied on similar applications as the former [2,3], and also by taking advantage of the versatility provided by its digital component, it can provide direct information of the phase in different fields of technology and science. Microscopy applications [4–6], optical metrological methods [7–9], imaging systems with 3-D applications [10,11], encryption of information with extended degrees of coding [12,13], among many others, are some of the fields where the DH has been widely used.

DH has reached its current state of development thanks to the possibility of using digital recording systems as CCD and CMOS cameras for the hologram recording and the utilization of fast personal computers for numerical reconstruction of the digitally recorded holograms [14–16]. The digital pre- and post-processing of both, the recorded and reconstructed holograms, have made possible the recovering of the store information in the holograms with the best possible degree of quality and at greater easy than in its optical counterpart. For example, in DH is possible to remove the zero order of diffraction and the twin image with almost null effort enhancing the displaying of the reconstructed image [17,18] , something hardly done in optical holography. As both optical and digital holography utilize mainly coherent light sources, they both suffer from speckle noise. The great similitude between these two ways of doing holography has also made possible the adoption of the similar methods to reduce that coherence noise [19,20], but the digital component of DH has helped to envision purely numerical approaches to diminish the speckle noise in the reconstructed images [21,22].

The sharing of the same basic physics principles between the optical and digital holography has also invited to export the rules of operation applicable in the former to DH with almost no analysis. One of these rules is the needed ratio of intensities between the reference and object waves to perform the correct recording of the hologram in such way that one can obtain the best possible reconstructed holographic image. Those trained in optical holography know that the quality of the holographic reconstruction resorts on the contrast of the recorded fringes that constitute the hologram. Then, the theoretically the ideal ratio of intensities between the reference and object waves is 1:1 [23]. However, detailed experimental studies that consider the multiple features of the holographic plates and the developing chemical process, have led to different ratios as the most appropriate [23].

The 1:1 ratio of intensities between the reference and object waves has been also adopted in DH as a rule of thumb for recording the digital holograms with maximum contrast while avoiding any digital camera saturation. The study of the ratio between reference and object waves has been addressed in off-axis holograms, specifically, using the heterodyne detection effect allowing the detection of extremely weak signals [24,25]. Up to the best knowledge of the authors, there are no further studies on this regard. With the aim of introducing insight on this subject in DH, we present an experimental study