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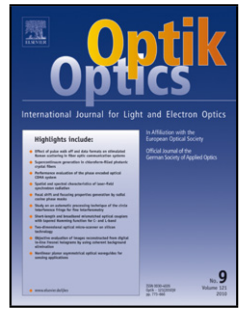

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Author: Mindaugas Andrulevičius Linas Puodžiukynas Tomas Tamulevičius Sigitas Tamulevičius

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Diffraction efficiency and noise analysis of hidden image holograms

Mindaugas Andrulevičius [a, b,*], Linas Puodžiukynas [a, b], Tomas Tamulevičius [a, b], Sigitas Tamulevičius [a, b]

[a] *Institute of Materials Science of Kaunas University of Technology, K. Baršausko str. 59, LT-51423 Kaunas, Lithuania*
[b] *Department of Physics, Kaunas University of Technology, Studentų str. 50, LT-51368 Kaunas, Lithuania*

The simplified approach for analysis of hidden image holograms is discussed in this paper. Diffraction efficiency and signal to noise ratio of reconstructed images were investigated using direct measurements technique and digitized image analysis employing “ImageJ” software. All holograms were recorded in a photoresist layer spin-coated on glass substrates applying laser interference lithography technique. Both analogue and digital analysis approaches showed the similar results thus confirming the appropriateness of the used analysis methods. It was found that holograms recorded at higher laser energy densities demonstrated improved diffraction efficiency and reduced signal to noise ratio of the reconstructed image. The best diffraction efficiency at sufficient signal to noise ratio was obtained using exposure energy density in the range from 150 to 200 J/m^2 during the hologram writing process.
Keywords: hologram, laser interference lithography, diffraction efficiency, signal to noise ratio.

1. Introduction*

During the last years, growing numbers of counterfeiting and piracy were stated [1]. Consequently, it increased the demand on documents security and brand authentication. Holograms and Optically Variable Imaging Devices (OVIDs) are the most widely used optical methods for security and authentication [2–4].

Applications of holograms or OVIDs in some cases require stringent security; thus, holograms with increased security features can be used [4]. It can be accomplished by merging different types of holography methods, i.e., the rainbow hologram can be combined with dot-matrix hologram in the same area [5]. The other approach is realized by replacing the part of one type hologram with the other type of hologram, i.e., part of the hologram is recorded employing Electron Beam Lithography (EBL) while the rest of the image is formed employing Laser Interference Lithography (LIL) [6]. The main goal of this consolidated lithography approach is to increase difficulties for potential forgery: both methods require a separated set of sophisticated equipment and appropriate knowledge of both techniques.

For demanding security applications, it is recommended to use advanced security features that are not visible for a naked eye under natural illumination, but the “hidden” image would become visible illuminating the designated area on the hologram with a monochromatic light source. Recording process of such dot-matrix hologram containing the invisible image is described in [7]. Only part of the image is visible when hologram is viewed in daylight (polychromatic) illumination. The diffracted beam reconstructs hidden the part of the image, if monochromatic laser beam illuminates surface of the hologram. The hologram is named “hidden image hologram”, since this part of the recorded picture can be seen only under monochromatic light illumination. Such hologram possess increased security feature due to this additional part of hidden image.

The other hologram recording process, described in [8], is widely used to record the so called “diffuse-object” holograms using LIL method. There the hidden image is produced at the first step of this process. It is visible only under monochromatic light illumination. The security features of combined hologram can be improved combining this hidden image with normally visible hologram. On the other hand, the combining multiple exposure process in one hologram can be difficult task due to the alignment complexity and differences in energy densities used during recording process and therefore different developing times. Each process should be investigated separately in order to achieve the best quality of combined images and overcome mentioned technological difficulties. Diffraction efficiency (DE), resolution, and signal to noise ratio (SNR) are the most important parameters of the hologram image quality [8–11]. Therefore, during hologram recording it is important to obtain high diffraction efficiency and high signal-to-noise ratio. SNR of holograms decreases when higher exposure energy density is used for hologram recording process [8]. On the contrary, diffraction efficiency of these holograms showed the opposite behaviour, when R-10 bleacher was used for silver halide hologram processing. Therefore, the exposure energy density should be carefully chosen in order to maintain high image quality of the hologram. Investigation of diffraction efficiency and signal-to-noise ratio of holograms recorded in photoresist layer and their dependence on the used exposure energy density are the main objectives of this work. Several evaluation approaches were employed and compared for the diffraction efficiency and SNR investigation.

*Corresponding author. Tel.: +370-37-313432; fax: +370-37-314423.
E-mail address mindaugas.andrulevicius@ktu.lt (M. Andrulevičius)