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Generation and Replication of Computer Generated Hologram

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***Abstract*—In this paper there are presented all technological process of computer generated hologram from design to mass production. It represents influence of all technological steps into quality of the final product. Also initial picture, its hologram and reconstructed image are presented.**

Index Terms— computer generated hologram (CGH), Fourier transformation, Gerchberg-Saxton algorithm.

I. Introduction

Replication technology plays an important role in the production of microstructures. The most popular replication technologies are hot embossing, UV embossing and injection molding, and etc. They enable low-cost mass production of optical microstructures and nanostructures. Replication technologies reach extremely high resolution, while it could be merged with macro objects (millimeter or centimeter range). Therefore this technology could be applied for production of optical elements and modules. But good replication result depends not only from good quality of high-resolution mould [1]. Quality covers all steps of microstructures creation form the design to mass production, which are presented in the Fig. 1.

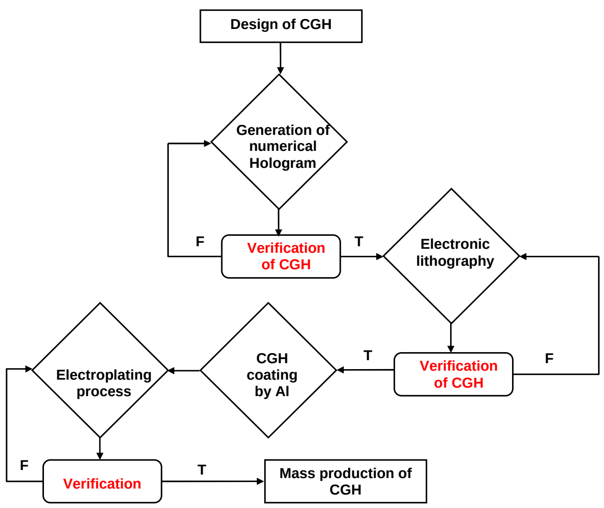

Fig. 1. Algorithm for manufacturing of microstructure: from design of CGH to mass production

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Especially it is important for formation of high aspect ratio computer generated hologram (CGH). Because they have been widely used in optical information processing, interferometry and diffractive optical elements, etc. [2]. Compared with optical holography, CGH is flexible in design and has good repeatability. Conventional CGH fabrication method requires a number of steps, including design of CGH, generation of numerical hologram, electronic lithography, CGH coating by Al, electroplating, and mass production [3], [4].

II. Computer Generated Hologram

Computer generated Fourier holograms (Fourier CGH) are widely used for recording of microstructure with complex profile. One of the main problems that final hologram doesn't contain enough information for full object wave reconstruction, because only the intensity distribution is used to record the Fourier hologram [5]–[7].

The CGH design techniques fall into two general categories: input/output techniques and iterative design techniques. All iterative design techniques are based on the phase retrieval algorithm proposed by Gerchberg and Saxton [8], [9]. The schema of algorithm is shown in Fig. 2. These techniques are computationally efficient due to the use of a fast Fourier transform (FFT) [10]. For the original Gerchberg–Saxton algorithm, the phase constraint is that the element is phase only, the amplitude is normalized to one at each iteration, and directly quantized to the number of phase levels required in the design. The output constraint forces the target to match the desired output intensity leaving the phase of the output unchanged. The major problems with the Gerchberg–Saxton algorithm for diffractive optic design are that it is dependent on the initial phase estimate and stagnates readily due to the direct quantization of the phase profile [11].

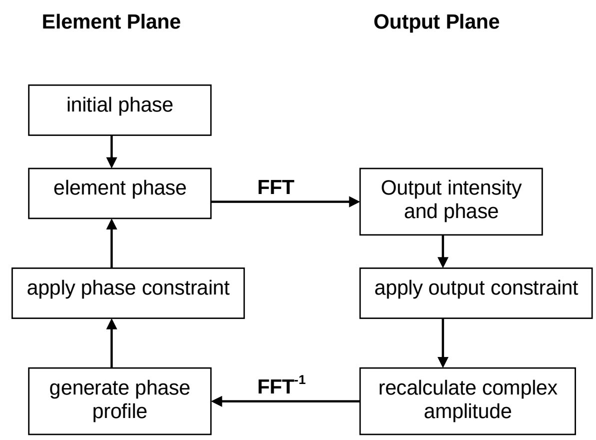

Fig. 2. A schematic representation of the Gerchberg-Saxton algorithm.

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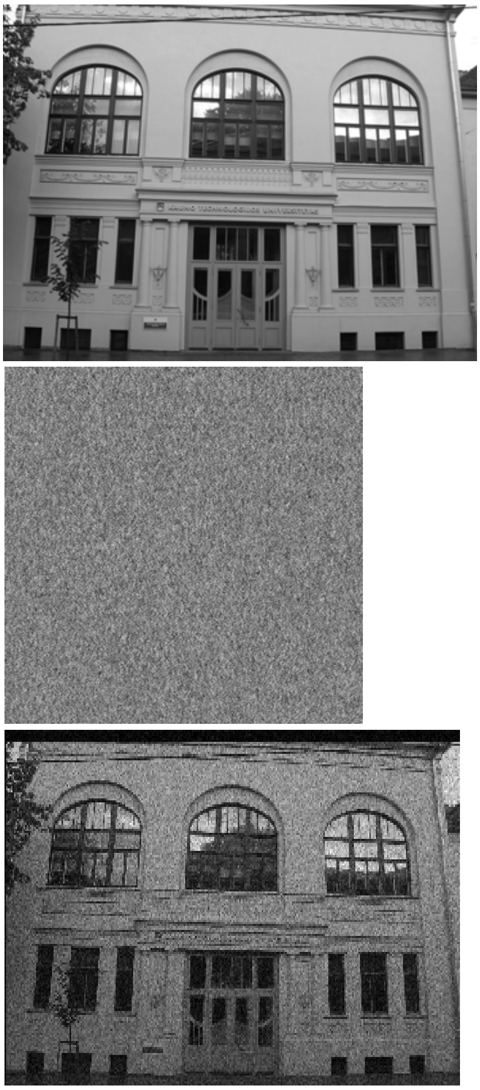
The process of CGH formation was implemented by means of the program developed within MATLAB.



a) b) c)

Fig. 3. Initial gray scale image of the building of International Studies Centre of Kaunas University of Technology (a), computer-generated hologram (b), and reconstructed CGH (c).

The buildings photo of International Studies Centre of Kaunas University of Technology (Fig. 3a) was selected for representation of CGH creation algorithm. CGH was created by applying Fourier transformation with GS algorithm (Fig. 3b). The algorithm was run for 100 iterations. Generated hologram (Fig. 3b) was checked using the inverse Fourier transformation (Fig. 3c). A program was developed with MATLAB for the purpose of reconstruction of the hologram. In the holographic map (Fig. 3b) black colour means a particular place (point, mark) that is not displayed. The white colour means the maximum doze (the map has 8 levels).

The quality of the numerically generated image can define by calculating the parameters:

1) The mean square error [12]: *MSE* as the difference between the calculated intensity and desired one from initial image file;
2) The diffraction efficiency: as the ratio between the intensity in the signal window and the whole diffracted intensity;
3) The contrast in a given image: $\frac{Intens_{\max} - Intens_{\min}}{Intens_{\max} + Intens_{\min}}$, where $Intens_{max}$ and $Intens_{min}$ are the maxim and minimum values from all pixel of the intensity image, respectively [13].

Computer generated hologram is transferred into polymer using E-beam lithography (EBL). EBL is the most commonly used technique for nanolithography. The resist deposition by spin coating, electro beam exposure and resist development is component of this process [7], [14].

Then it is necessary to create high ratio metal mold. Therefore electroforming is used. It is a process by which metal is deposited on the surface of a substrate. Often used for its excellent surface finishes and ability to create uniform parts of varying thickness, electroforming has more recently been incorporated into the nanofabrication industry. Electroforming is preformed by running a current through a positive anode “target” and a negative cathode. Many different metals and alloys can be used [15]–[18].

And finally mold could be used for the mass production of replicas using different replication technologies: hot imprint, UV embossing, injection molding and etc.

III. CONCLUSIONS

Technological process of computer generated hologram manufacturing from design to mass production is presented. Hologram should pass all this process in the case to satisfy quality requirements. These holograms could be used for manipulation of an atomic beam, generation of optical phase singularities, realization of general nondiffracting beams and etc.

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