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Reconstruction of a Contrast Inverted Image by Diffraction on the Sequentially Recorded Holographic Grating and of the Phase Image

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Abstract: A complex experiment was carried out for the first time by combining holographic and photographic recording on the registering medium. The aim of the work was the verification of the relevant assumption and in general observation of influence of additional modulation on the diffraction characteristics of the holographic structure. For the beginning the recording of the elementary hologram (diffraction grating) was performed and following photographic recording, i.e. photographic image imposition. As a result was obtained a contrast inverted image of the object without spatial filtration or phase contrast method by the diffraction on the superimposed to each other holographic phase grating and the phase image of the object. The sequentially holographic and photographic recording at the same area of the dichromate gelatin layer (DCG) was performed for this.

Keywords: Phase Contrast, Spatial Filtration, Phase Image, Amplitude Image, Photography, Holography

1. Introduction

Usually spatial filtration and phase contrast methods are used for increasing of contrast of the phase images of the objects [1-4]. For these methods it needs complex optical systems with corresponding spatial filters or phase plates. Development of new methods of photography and holography didn't give some new results for simplification and enhancement of imaging of phase objects. Only digital holography gives some practical results in this direction [5-8]. However there exists the possibility of obtaining of inverted contrast image of objects by combining usual holographic and photographic methods. Particularly, as it is known, light registration on the photoresist layers (for example on the dichromate gelatin layer - DCG) gives phase image of the amplitude modulated wave front of the influenced actinic light. In this case the exposition characteristics of these photosensitive materials usually are nonlinear and after of some energy of the exposure by the actinic light achieves to saturation [9, 10]. Therefore at the sequentially registration of two different light fields on the same area of the DCG layer it is possible to achieve the summary exposure energy when registering medium will achieve saturation and subsequent recording process stopped.

So in the overlapping areas of the two images the recorded information can completely erase. From this point of view the result of sequentially recording of the holographic diffraction grating and usual photographic image in the same area of the registering medium is of interest.

2. Experiment

As a registering medium was used photo plate with gelatin layer sensitized according to Lin method by the bathing in 5% water solution of the dichromate ammonia [11]. After drying of the photo plate the recording process in the obtained layer was investigated. For this the photo plate was exposed by radiation of the He-Cd laser (λ=441.6nm). Irradiation of the photo plate was carried out step by step in the different areas at the different exposure energies from 75×10^{-3}J up to 10J.

Figure 1 shows spectral transmission characteristics of the layer of the dichromated gelatin (DCG) before and after irradiation in the increasing of exposure of irradiation by He-Cd laser (λ=441.6nm).

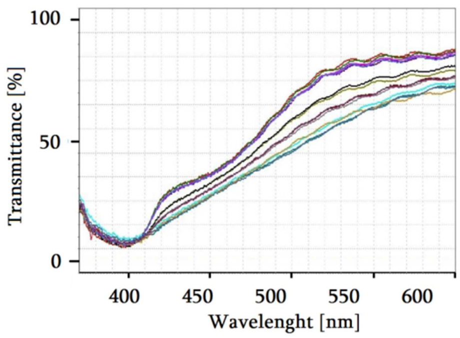


Figure 1. *Spectral transmittance characteristics of DCG layer at the increasing of the exposure energy.*

The laser radiation density at exposure was 0.15W/cm^2. As it follows from Figure 1 the absorption of the dichromate gelatin layer increases at the increasing of the exposure energy. Figure 2 shows the dynamic of changing of the spectral transmission characteristic (increasing of absorption) of the DCG layer at the increasing of exposureenergy. According to Figure 2 registeringmedium saturates at the exposure energy 7-10J, the recording process is ceasing and further registration of light does not occur. On the basis of these results the sequential recording of holographic grating and photographic image on the one same area of the given material was carried out. The scheme of the photographic registration of image on the dichromated gelatin layer is shown in Figure 3 a. The amplitude images of 2-D transparent objects (Figure 3 b,c) is projected by the objective on the glass plate covered by dichromate gelatin layer (DCG). As the actinic light the radiation of He-Cd (λ=441.6nm) laser was used. As is known, in this case in the layer the latent image of an object with low amplitude modulation is formed [10, 11]. After corresponding technological processing the latent image with low amplitude modulation is transformed in the phase image with high phase modulation. In addition the layer is already becomes transparent as for the recording wave also in all visible range of spectrum [10, 11]. Figure 4. shows the views of the obtained phase images transmitted collimated green beam of the laser pointer (532nm) after spatial filtration by the point mask located the focus ofthe projection lens (Figure 3a). Figure 5 shows the optical scheme of the holographic recording of the diffractive grating. Extended and collimated laser beam of the He-Cd laser is dividing on two beams that are overlapping by deflecting prism in the plane of DCG layer. Therefore on the photosensitive layer is recorded the interference pattern of two plane wave of the laser radiation. In this case the latent image of the interference pattern i.e. holographic grating on the photosensitive layer is fixing.

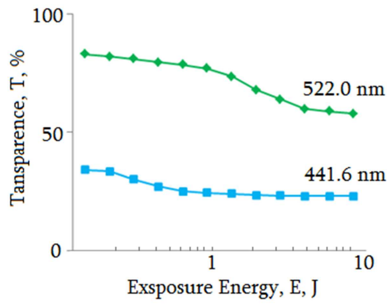


Figure 2. *The dynamic of the photographic process in the DCG layer for the light wave λ=441.6nm.*

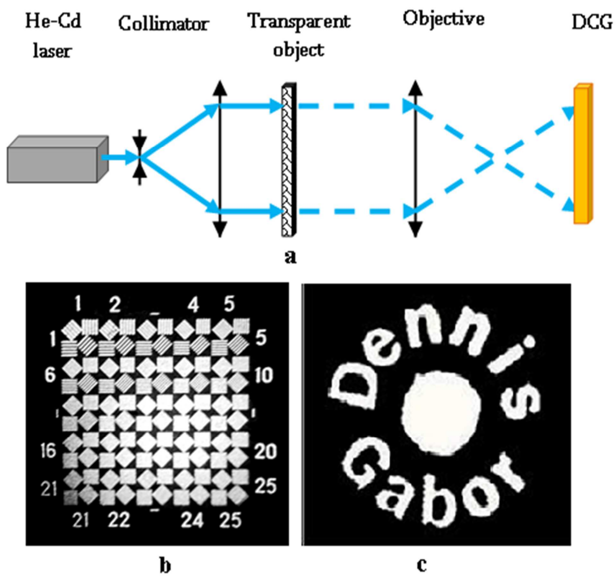


Figure 3. *The scheme of the photographic registration (a) and the views of transparent objects (b,c).*

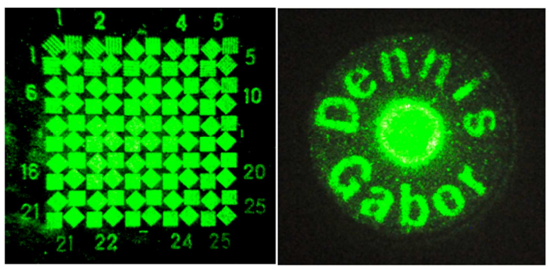


Figure 4. *The views of phase images of the objects after spatial filtration.*

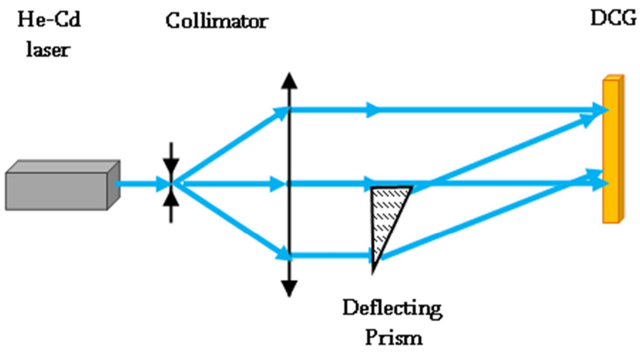
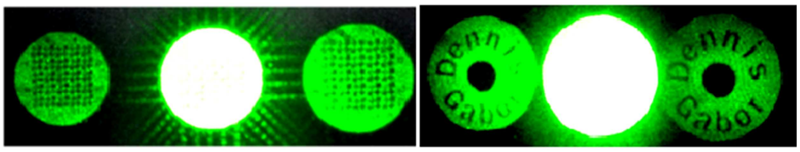


Figure 5. *The optical scheme of the recording of holographic grating.*

After corresponding technological processing of the layer the diffraction grating with low amplitude modulation is transformed in sufficient efficiency diffraction grating with high phase modulation [11].

So, at the first stage was recorded holographic diffraction gratings (Figure 5) and at the second stage was registered the photographic images of the transparent objects (Figure 3) on the recorded gratings at the one same area of the DCG layer. Therefore, in this case the latent images of the object and of the holographic grating are superimposed each other. After technological processing holographic phase gratings and phase images of the objects superimposed to each other are obtained. The exposure energies of the holographic and photographic registration processes was selected such that after enlightenment of the registered complex image by plane wave, the diffraction on the holographic grating gives contrast inverted images of the objects (Figure 6 a,b). For thereconstruction of recording images the collimated laser green beam from a laser pointer (λ=532 nm) was used. Figure 6 shows 0 and ±1 diffraction orders obtained by the diffraction on the combined structures containing holographic phase grating and photographic phase image. As it follows from Figure 6 the diffraction on the obtaining combination of the holographic grating and phase images gives a contrast inverted amplitude images of the initial objects.



a b

Figure 6. *The reconstructed images by diffraction.*

3. Analysis

In the proposed approach, the sequence of registration of the diffraction grating and the image is of importance. Particularly, when recording the image of the object in the first stage and the subsequent registration of the diffraction grating at the same area of DCG layer, it is more difficult to obtain such a result. This is due to the fact that in the regions of the image with the maximum exposure, the recording of the diffraction grating is already unattainable. Naturally, the selection of the energy exposure at each stage of recording the diffraction grating and phase imaging is great importance in this case.

Obtaining of similar results is possible in the every photosensitive material in the use of analogous approach. However more interesting are materials giving phase images of the objects. From this point of view the most convenient materials are photoresists and among them dichromated gelatin (DCG) but will be interesting also application of registering medium with Weigert's effect (polarization sensitive materials) [10-14]. In this case together with image inversion and improvement of the contrast of the phase images of the objects the polarization transformation effects will also possible that is important for optical-information technologies [15, 16].

It's clear that such a result of obtaining of contrast image of the phase object and it's inversion is observed in the all orders of diffraction (Figure 7). It's important also that there is observed anenlargement and decreasing of images in the ± orders of diffraction, which is interesting for microscopy problems. Therefore it's important more general investigation of this approach and corresponding theoretical research of this problem what will be realized in the nearest future in the next investigations.

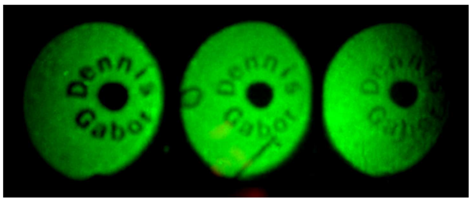


Figure 7. *The inverted contrast image of the object in +1, +2, +3 orders of diffraction.*

4. Conclusion

According to obtained results it is possible realization of obtaining of contrast amplitude image of the phase object without spatial filtration and phase contrast method by combining of photographic and holographic recording. It is possible also inversion of initial image. These results may some application in the optical information processing and in the microscopy of phase objects.

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