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Improved efficiency reflection holograms of diffusely reflecting objects

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Various factors influencing the construction of reflection holograms have been studied. They include the geometry of holographic setup, the intensity ratio of reference to signal beam and the optical density of recording material. The influence of the chemical processing on the efficiency of the reflection holograms is also considered. The type of developer and the developing time, as well as bleaching procedures, were experimentally optimized. The new technics of presoaking is given.

Reflection holograms recorded on thick emulsion layers have special properties, such as great information capacity, white light reconstruction ability, applicability to multicolour holography. The recording of such a hologram consists in spatial modulation of absorption coefficient or refractive index in the recording medium. For reflection holograms during the image reconstruction the light is diffracted under the angles defined by Bragg condition and then the highly efficient image is produced. This image is of great colour selectivity and high angular sensitivity.

The restriction concerning minimum emulsion thickness, at which the recording has the above mentioned properties, has been formulated by KOGELNIK [1] and is expressed by a dimensionless parameter $Q \geqslant 10$, where $Q = 2\pi\lambda d/nT^2$, λ — wavelength of the recording light beam, d — thickness of emulsion, T — distance between the interfering planes in the hologram, n — the average refractive index of the emulsion. The properties of the image reconstructed from the reflective hologram depend on a number of recording parameters, and on the individual features of the holographic object, photosensitive material characteristics and so on. The optimization conditions published so far have concerned transparent testing objects. We are using here these conditions to recording volume holograms of a diffusely scattering object.

In the holographic system applied to produce reflection holograms, the reference and object beams fall on a holographic plate from the opposite sides. Due to finite resolution of the plate the angle between the reference and object beams is limited. For the Agfa-Gevaert 8E 75B plates and He–Ne laser used in our lab the maximum value of this angle should not exceed 140° (fig. 1). The diffusing object used in our experiments was a porcelain statuette of sizes $120 \times 90 \times 30$ mm. It was stated out experimentally that, according to [2], the best results are achieved

when the intensity ratio of object to reference beam is close to 1. The required average optical density of the plate should be greater than that for transmission holograms [1, 3]. In the series of holograms produced by

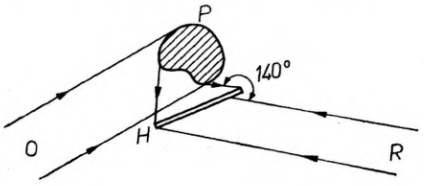

Fig. 1. Geometry of holographic system used for recording of reflection holograms. *P* – object, *O* – illuminating beam, *R* – reference beam, *H* – hologram plate

us the optical density ranges within the 1.7–3 region and the best reconstructed image is obtained for the optical density equal to 3. The diffraction efficiency of reflection holograms grows with increase of the holographic plate density, however, at the same time an unwanted increase in spectral width of the reconstructed image [1–4] is observed. The optimal values of the optical density should be fitted experimentally taking into account the plate properties and the geometry of holographic system. If, for instance, the object is very close to the plate, as in our case, the increase in the spectral width influences on the reconstructed image quality only slightly.

The influence of the chemical processing on the quality of holographic image should be also considered [5, 6]. The results obtained by application of high-contrast developer D-19 and appropriate long developing time (12 min. at 293K temperature) are much better than those produced by G3p developer recommended for Holtest 8F 75B emulsions. The further processing stage – the fixing – causes washing out the silver bromide crystals from the emulsion, so a shrinkage of emulsion may occur during drying. Then, the distances between the interfering planes diminish, which cause that a shorter wavelength should be used for image reconstruction,

Fig. 2. The image reconstructed with white light from a reflection hologram. The change in colour from red to green is caused by emulsion shrinkage

than that used for recording [7] (see fig. 2). For holograms of high absorption (high content of metalic silver) the effect of emulsion shrinkage is much weaker.

The emulsion shrinkage effect can be removed by bathing the hologram in a triethanolamine solution [8, 9]. The required concentration of triethanolamine depends upon optical density of the plate, emulsion thickness and so on. Hence, the conditions for removal of emulsion shrinkage must be fitted experimentally for each holographic plate. A new method applied to emulsion shrinkage correction consisted in soaking the emulsion with a solution of Canadian balsam in ethyl alcohol in volume ratio 1 : 1. The emulsion had been covered with a glass plate impending the evaporation of alcohol. The layer of Canadian balsam fills the irregularities of the surface and thereby diminishes the noise generated by surface scattering.

The chemical treatment evokes the greatest deformations in the surface emulsion layers, destroying the most external Bragg planes. The reduced number of active diffracting surfaces causes decrease of the diffraction efficiency of hologram. During the reconstruction of reflection holograms the greatest amount of light is diffracted by only a few planes closest to the reconstructing beam. Thus, the most advantageous reconstruction is achieved if the emulsion-side of the holographic plate during the exposure is directed toward the object beam. The first planes interacting with the reconstructing beam lay close to the glass and do not suffer from deformations.

Holograms of great optical density absorb considerable part of the reconstructing beam energy. For bleaching of the emulsion the absorption effect may be largely diminished. The maximum theoretical diffraction efficiency of unbleached holograms is 7.2 % while for bleached holograms it may reach even 100 % [1]. The bleaching methods consisting in replacing the metalic silver with bromide crystal give an increase in brightness of the reconstructed image with simultaneous increase of the background light level. This phenomenon is especially detrimental to reflection holograms. The most advantageous image is obtained by applying a bleaching composed of mercury chloride, ammonium chloride and potassium bromide, which replaces absolutly absorbing silver grains by crystals of mercury sulphide [3].

The image reconstructed from a reflection holograms without compensation of emulsion shrinkage, recorded on a Polaroid Land Roll Film Colour/75 Speed material is presented in fig. 2.

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Высокоэффективные отражательные голограммы рассеивающих объектов

Исследовано влияние разных параметров на образование отражательных голограмм, то есть геометрии голографической системы, отношения интенсивности пучков, образующих голограмму, оптической плотности голографической пластинки. Рассмотрена зависимость качества изображения, воспроизведенного по отражательной голограмме, от химической обработки и предложена оптимизация процесса проявления и отбеливания. Представлен новый метод удаления усадки эмульсии.