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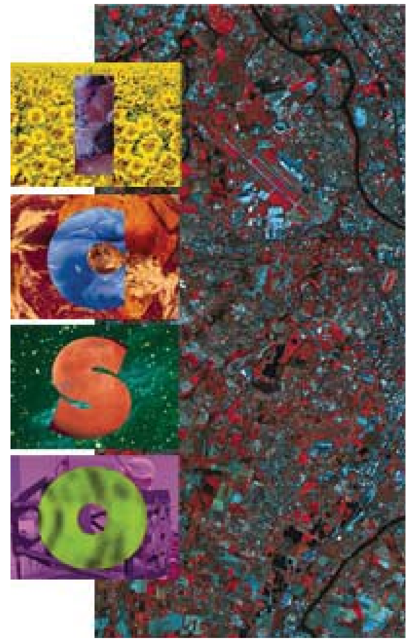

UV holographic filters

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UV HOLOGRAPHIC FILTERS

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***ABSTRACT** - A new approach to UV holographic filter's manufacturing, when the filters are the volume reflection holograms, working in UV region in the second Bragg diffraction order, is offered. The method is experimentally realized for wavelength of 266 nm.*

1-INTRODUCTION

The topical problem is a filtration of optical radiation in ultraviolet (UV) spectral range. Ultraviolet filters are important components of equipment, which uses in space researches, remote sensing, lidars. One of the well-known methods of manufacturing of UV filters is the interference method, in which the vacuum deposition of thin layers of determined substances is carried out. However, techniques of vacuum deposition are complicated enough and special equipment in UV spectral range is required in this case.

There is known a holographic method of filter's manufacturing when the filters are volume reflection holograms. Dichromated gelatin (DCG) can be used as recording medium. Traditional approach in this case includes a shift of the main reflection band of hologram to ultraviolet region. In paper [1] shift of the spectral band from visible to UV region was carried out by change of layer's moisture before exposure. By this method it was possible to achieve the spectral shift of the filter up to 355 nm. In paper [2] it was specified a possibity of the spectral shift from 480 nm up to 340 nm by using of special quartz prism glued with hologram filter. The filter worked with inclined beams of radiation.

We offer a new approach to UV holographic filter's manufacturing, when the filters are the volume reflection holograms, working in UV region in the second Bragg diffraction order. In our previous papers [3,4] it was shown, that the forming of Bragg diffraction maxima up to the 4-th order has been observed in a spectrum of reflection hologram in DCG at nonlinear recording. Unfortunately, DCG layer absorbs the UV radiation, that put in certain limitations on values of filter's spectral characteristics. The shorter wavelength is used, the less intensive signal of reflected radiation can be received even at the high diffraction efficiency of the hologram.

This paper is devoted to experimental realization of the offered method for wavelength of 266 nm. A choice of this wavelength is caused by fact that radiation of the 4-th harmonic of Nd laser is promising for application in space and atmospheric researches.

2. TECHNIQUE OF EXPERIMENT

As a recording medium the unhardened dichromated gelatin (DCG), fabricated in accordance with our technique [5], is used. The thicknesses of DCG layers, deposited on substrates, are equal to 1, 5, 10 and

23 μm. The quartz substrates by the size of 1.5 * 21 * 21 mm are used. The reflection holograms are recorded by Ar laser radiation at wavelenght of 488 nm. In our experiments the Denisuik scheme of hologram mirror recording is used; the mirror, forming object beam, is placed parallel to the substrate. After postexposure treatment substrate with hologram is protected by another quartz substrate and over on ends by sticky tape. It allowed to protect the hologram from influence of air humidity and to keep constancy of holographic parameters during several days. It is necessary to protect hologram by the substrate with the help of the optical glue, transparent in UV, for longer preservation. The optical parameters of the filters are controlled by transmission spectra. The spectra are measured directly after hologram's manufacturing by home spectrophotometer. A range of transmission measurement by this device is equal to 3-100%.

3. EXPERIMENTAL RESULTS

The transmission spectra of gelatin's layers of different thicknesses are measured for an estimation of own gelatin's absorption. Measured spectra are given in Fig. 1a,b,c. It is evident from Fig.1 that a boundary of gelatin transparency begins from 230 nm for all thicknesses. The bigger thickness of gelatin layer is used, the smaller part of the reflected radiation can be received as useful signal. The best conditions of radiation's reflection are realized with thicknesses of gelatin layer equal 1 and 5 μm. With thickness of DCG layer equal 23 μm the part of potentially reflected radiation will be close to 55 % of intensity of incident radiation.

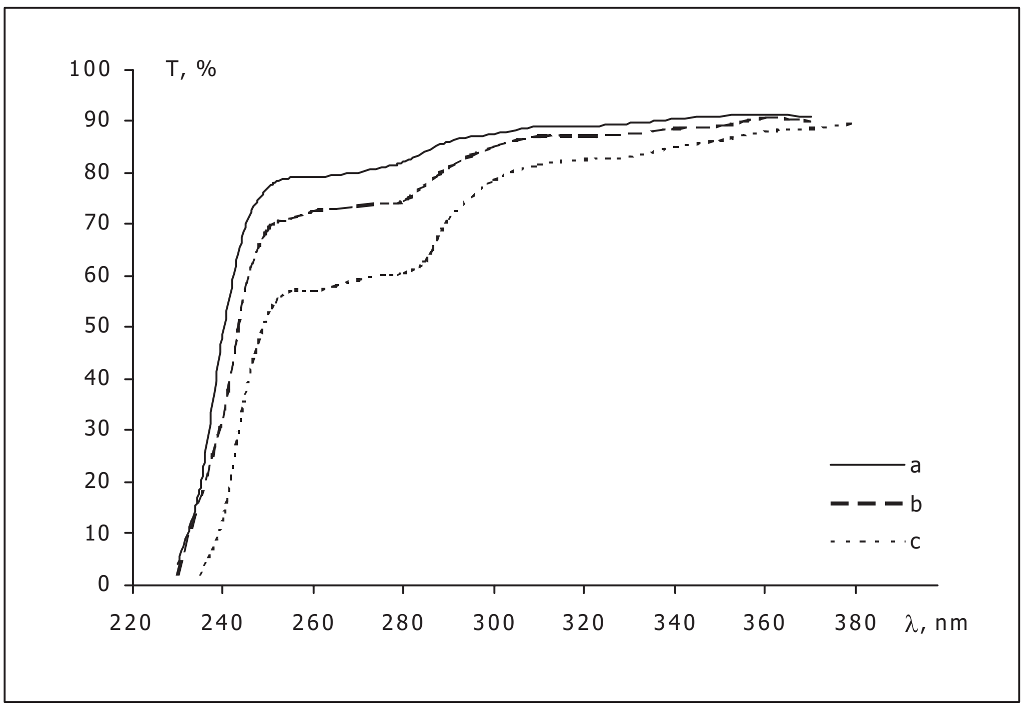

Fig.1 The transmission spectra of gelatin's layers of different thicknesses: a-5, b-10, c-23 μm

The experiments on recording of holographic filters are carried out for all thicknesses of DCG layers. A principle of nonlinear hologram recording and formation of diffraction maxima of other orders, namely 2-nd order, has been used. In this case the main maximum is present in transmission spectrum of hologram as band with λ_{min} = 505 nm. It is found from experiments, that a ratio of peak wavelengts in the 1-st and 2-nd orders: R= λ_{min} (1order)/λ_{min} (2 order) equals 1.9, but not 2, as one would think. This phenomenon has been observed our earlier [4] and has been explained by dispersion of gelatin's refraction index in visible and UV spectral range.

The exposure dependencies of transmission spectra are measured. The optimum expositions, at which the required spectral response of the hologram is formed, are determined. First of all technique of filter's manufacturing should provide getting λ_{min} of reflection band in required wavelength of 266 nm. Then the tasks of achievement of minimum possible transmission T_{min} in wavelength of 266 nm with greatest possible transmission outside of diffraction zone (T_{odz}) and minimization of filter's spectral half bandwidth (SHBW) are set.

Following peculiarity was revealed. With increasing density of exposure energy E_{exp}, a modulation of refraction index Δn increases, on the one hand, but light hardening of DCG layer grows, on the other hand. A position of λ_{min} is displaced in spectral region shorter 266 nm as a result of hardening growth. Because the task of getting λ_{min} in wavelength of 266 nm was priority, it was necessary to be limited by that value E_{exp}, which did not result going away from required wavelength. In result it was not always possible to achieve the maximum values Δn and diffraction efficiency of hologram, respectively.

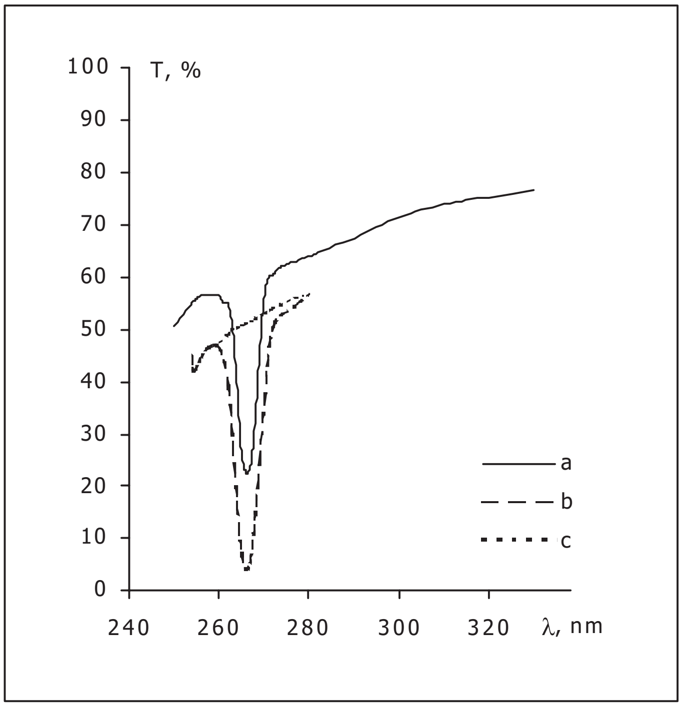

Fig.2. The transmission spectra of hologram filters in thicknesses equal to 5 (a) and 10 (b) μm, c-transmission of noise component of signal inside of the diffraction zone.

The best results are achieved at making of hologram filters in layer's thicknesses equal 5 and 10 μm. The transmission spectra for these filters are shown in Fig.2 a,b, respectively. The minimum transmission, received for thickness equal 10 μm, has made of 4% (Fig.2b). In spite of this a noise component of signal (which includes absorption and scattering of radiation by layer) has grown up to 50 % (Fig.2c). In this case substantial growth of light scattering by the layer has played its part. If in the visible spectral range the scattering is unsignificantly counted on a magnitude of transmission outside of the diffraction zone, then in UV range this effect especially is expressed.

The transmission spectra for filters in DCG layers with thicknesses equal 1 and 23 μm are shown in Fig.3 a,b, respectively. The postexposure treatment of 1 μm layer is carried out at higher temperatures than for 23 μm layer for achievement of high values of refraction index modulation. The treatment of the layer at higher temperatures entails formation of scattering centres in the form of cavityes and microcracks in layer, that result increase of noise and lead to broadening of spectral band. At making filters in DCG layer with thickness of 23 μm more soft conditions of postexposure treatment are used for prevention of noise increasing. SHBW becomes much less in this case.

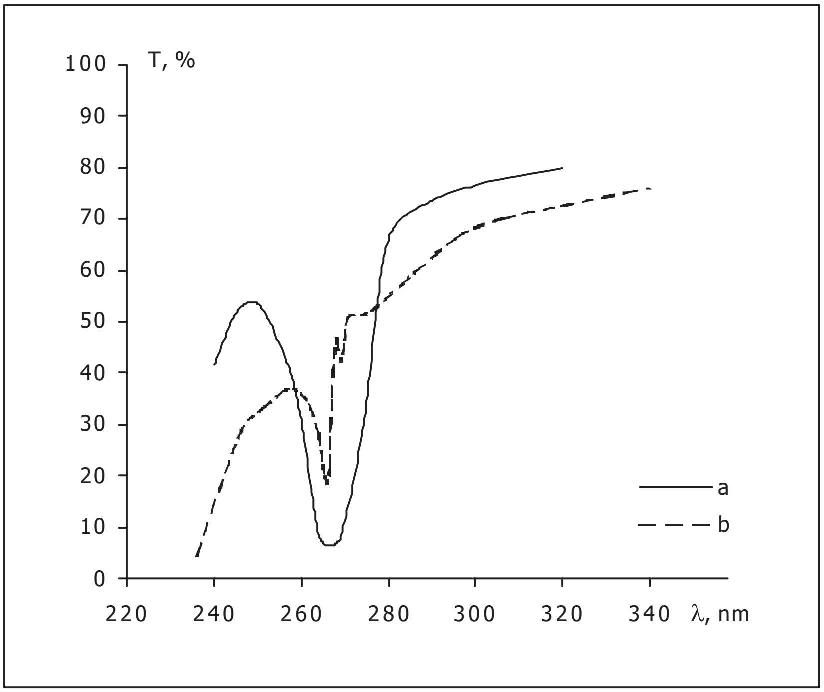

Fig.3. The transmission spectra of hologram filters in layer's thicknesses equal to 1 (a) and 23 (b) μm.

Unfortunately, instrument for UV spectral region, which we own, has not allowed us to measure reflection spectra of filters. However about efficiency of the reflective hologram and width of the spectral response it is possible to judge according to a differential spectrum, isolated from transmission spectrum of the hologram by differential subtraction of noise transmission spectrum inside of the diffraction zone. Such the differential spectrum for thickness equal 10 μm is submitted in Fig.4. It is received from spectrum 2b in Fig.2 by differential subtraction of spectrum 2c.

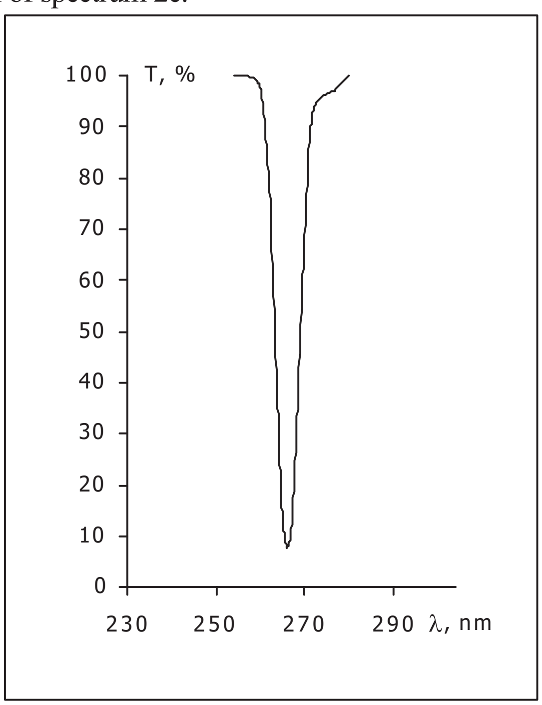

Fig.4. The differential spectrum of hologram filter in layer's thickness equal 10 μm, received from spectrum 2b in Fig.2 by differential subtraction of spectrum 2c.

Thus, offered by us the method of manufacturing of holographic filters in UV spectral range, working in 2-nd Bragg diffraction maximum, is quite efficient, that is demonstrated on an example of filters for wavelength of 266 nm. For making of filters for longer or shorter wavelengths in UV, it is necessary the main diffraction maximum to move in corresponding, previously calculated, position in visible range. This moving can be realized by known techniques, about which it was told in [3,4]. The holographic filters are easy in making and can successfully compete with interference ones.

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REFERENCES

[1] J.Crespo, M.Pardo, M.Sattore, J.A.Quintana, " Ultraviolet spectarlly responsive holograms in dichromated gelatin", *Appl.Opt*.,v.32, N 17, pp.3068-3072, 1993.

[2] V.V.Smirnov, L.M. Piljak, T.V. Shedrunova, I.B.Muravjova, Novoselski V.V., "Holographic high - reflection filters in dichromated gelatin layers", *Proc.SPIE*, vol.2108, pp.94-100, 1993.

[3] Z.N.Kalyashova, E.V.Kalyashov, G.A.Cheremisina, D.I.Matveeva, "Intensive Bragg harmonics in reflection holograms in dichromated gelatin.Part 1", *Proc.SPIE,* Vol.3011, p.279-284, 1997.

[4] Z.N.Kalyashova,E.V.Kalyashov,G.A.Cheremisina, "Intensive Bragg harmonics in reflection holograms in dichromated gelatin. Part 2", *Proc.SPIE*, Vol.3011, p.285-292, 1997.

[5] Z.N.Kalyashova, Yu.Ye.Kusilin, A.G.Mikhailova , Patent RU 2008716, 1994.