Suppression of light diffraction at the relative index of refraction close to unity. Part I

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Significant suppression of light diffraction by a screen at the relative index of refraction close to unity has been revealed while using IKS3 and SS8 colored glass plates as screens, placed in a cell filled with dimethyl phthalate or its solution in benzyl alcohol.

As known, a screen is given a passive role in the diffraction theories based on the concept of secondary waves, i.e., it only cuts out a part of a wave front.[1] However, in reality, the resulting diffraction pattern depends on different properties of the screen.

In particular, amplification of the edge wave by several times and the corresponding variation of light intensity in the diffraction pattern bands have been realized in Ref. 2 when changing a thin screen (razor blade) by a thick one with a flat face (several mm wide) parallel to the passing by light.

The significant light attenuation in maxima and its amplification in minima of the diffraction pattern by a practically opaque screen has been experimentally established in Ref. 3 in the case of a screen thinning to $5.4 \cdot 10^{-2}$ μm or decreasing the screen material density to small values.

In this paper, the experimental results on significant suppression of light diffraction by screens placed in a liquid are considered.

The optical arrangement of the experiment is shown in Fig. 1, where S' is the image of the slit S, Sc is a thick screen placed at a distance $l = 12.85$–14.1 mm from S' and $L = 110$ mm from the plane of scanning the diffraction pattern, respectively, Ss is the scanning slit of 50 μm in width, PMT is a photomultiplier, *1* are the rays of incident light, *2* are the edge rays that appear due to deflection of the rays of incident light to both sides from their initial direction of propagation in a liquid or in the air near the edge a (Refs. 4 and 5), $-H$ is the distance from the geometrical shadow (g.s.) boundary to maxima and minima of the diffraction pattern formed due to interference between the incident and edge light rays, H is the distance from g.s. to the points of incidence of the edge rays within the shadow; K is the cell of 12-mm width with transparent windows, made from 1.5-mm thick optical glass, and a screen placed at 4.4 mm distance from the input window with the screen side ab being normal to the window plane.

The slit S, not shown in Fig. 1, is illuminated by a parallel beam of green light ($\lambda = 0.53$ μm) from an incandescent lamp radiation, S' is the image of the slit S constructed by a "Yupiter-8" objective, width of S and S' is 23 μm. The light beam is limited by means of a 5.6-mm wide slit, at the level of $\min_2$ in the diffraction pattern formed by the slit S, placed in front of the objective. Because of low light intensity in $\min_2$, when the screen is taken out of the beam, the intensity distribution over the beam width in the plane of the Ss slit is close to the intensity distribution in the diffraction pattern by the slit S.

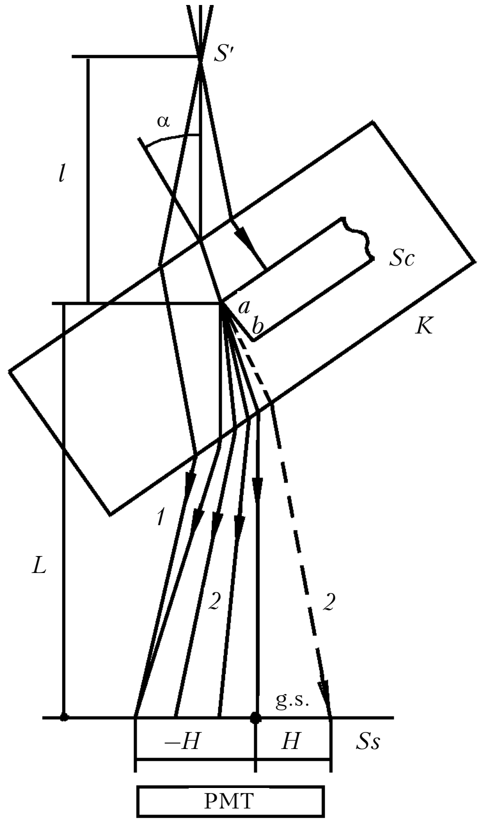

Fig. 1. Optical arrangement of experiments on light diffraction by a screen placed in the air or in a liquid.

To obtain the highest intensity of the edge light, the screen is placed by its edge a at the beam axis following the criterion that the light flux coming from S' is halved. As the screen, plate made from IKS3 and SS8 colored glass with polished sides have been used (the width of the side ab is 3 mm) with the right angles a and b, the absorption coefficients K_λ equal 6 and

0.711 at the above-mentioned λ, and the refractive index n_3 equal to 1.5437 for IKS3 and 1.5227 for SS8.

To study diffraction patterns of classical light diffraction by a thin screen, the cell is tilted about the edge *a* at the angle α = 19° between the cell normal and the beam axis so that the side *ab* comes off from the beam axis, since, as shown in Ref. 2, in that case a thick screen becomes practically equivalent to a thin one if the tilt angle is larger than 11°.

While studying, there were scanned the diffraction patterns formed by IKS3 and SS8 plates, placed in the air and dimethyl phthalate with $n_3 = 1.5205$, and by an IKS3 plate, placed in benzyl alcohol solution of dimethyl phthalate ($n_3 = 1.5451$).

An IKS3 plate, opaque at thickness of 3 mm, is partially transparent near the edge *a*. (A beam, refracted into the plate from dimethyl phthalate at the distance of 53 μm from the edge, is attenuated only by 31.6-times at the above-mentioned α). To exclude superposition of the refracted light and the diffraction bands, the plates used in the experiments under consideration were optically denser than the liquid in the cell. In this case, the light refracted into the plate propagates to the right of the axis of an incident beam passing through the edge *a* and superposing the edge light within the geometrical shadow of the screen.

The experimental results are given in the Table and Fig. 2, where I_p is the light intensity at maxima and minima of the diffraction pattern and at the boundary of the geometrical shadow, I_c is the corresponding intensity when the screen is out of the beam, I is the light intensity (in relative units) in the scanning plane; curves *1* and *2* characterize the intensity distribution when the screen is in and out of the beam.

As is seen from the Table, the placement of an IKS3 plate in dimethyl phthalate results in compression of the diffraction bands contrast, which consists in the decrease of relative light intensity I_p/I_c at maxima and its increase at minima.

At a further decrease of the relative index of refraction n_{rel} by means of solving dimethyl phthalate in benzyl alcohol, the bands contrast gradually falls down to its minimum at $n_{rel} = 1.0054$ and differs essentially from the pattern contrast for the plates placed in the air, which is evident from Fig. 2.

Since the contrast of the diffraction pattern decreases with the decrease of n_{rel} one could expect that the contrast should reach its minimum at $n_{rel} = 1$, however this is not the case. Thus at $n_{rel} = 1.0043$ the diffraction pattern turns out to have higher contrast than that at $n_{rel} = 1.0054$ and, moreover, the contrast continues to increase at the further decrease of n_{rel}.

Such a peculiarity is seemingly the consequence of the existence of an intermediate layer in the plate near the interface with the refractive index gradient. The reasons for the layer origin were considered in Ref. 6. Besides, based on Refs. 7 and 8, its origin can be explained by the probable change of colorant concentration near the surface of colored glasses, which evidently depends on the mobility of colorant molecules.

Based on the existence of the intermediate layer, one may conclude that the lowest contrast of the diffraction bands (at $n_{rel} = 1.0054$) corresponds to the decrease of the refractive index n of this layer from the n value of the plate down to the n value of the solution. As a result, the relative refractive index at the interface $n_{rel.i}$ equals to unity.

The decrease of n and its small value are confirmed by the light amplification at the initial part of the screen shadow in the absence of refraction at the interface, which is due to the small beam deflection toward the intermediate layer with larger n.

Deterioration of the contrast of the diffraction bands is an evidence of a decrease of the efficiency of deflecting the edge rays *2* at $n_{rel} \to 1$, as this decrease results in narrowing of the zone, where the rays *2* deflect within the previous range of angles, and the corresponding reduction of the deflected light flux.

Relative light intensity in diffraction patterns of IKS3 and SS8 plates at different values of the relative refractive index

Band	IKS3				SS8	
	in dimethyl phthalate; $n_{rel} = 1.0152$; $l = 13.1$ mm	in air; $l = 14.1$ mm	in dimethyl phthalate solution in benzyl alcohol; $n_{rel} = 1.0054$; $l = 13.1$ mm	in dimethyl phthalate solution in benzyl alcohol; $n_{rel} = 1.0048$; $l = 13.1$ mm	in air; $l = 14.1$ mm	in dimethyl phthalate; $n_{rel} = 1.0047$; $l = 12.85$ mm
	I_p/I_c					
max_1	1.333	1.37	1.219	1.272	1.349	1.283
min_1	0.783	0.742	0.881	0.829	0.745	0.807
max_2	1.238	1.324	1.136	1.128	1.336	1.161
min_2	0.764	0.783	0.919	0.912	0.769	0.864
max_3	1.202	1.218	1.088	1.066	1.254	1.155
min_3	0.809	0.773	0.931	0.917	0.749	0.864
max_4	1.218	1.311	1.051	1.056	1.347	1.112
min_4	0.698	0.718	0.947	0.908	0.735	0.852
max_5	1.216	1.25	1.094	1.103	1.404	1.197
min_5	0.882	0.819	–	–	0.83	0.824
g.s.	0.235	0.235	0.497	0.312	0.275	0.344

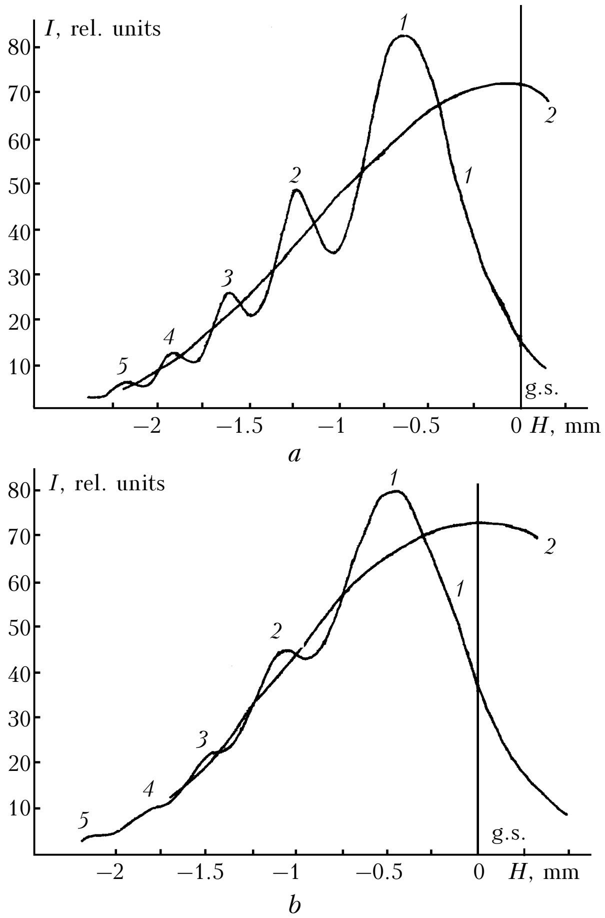

Fig. 2. IKS3-plate diffraction pattern when the plate is in air (*a*) and in dimethyl phthalate solution in benzyl alcohol at n_{rel} = 1.0054 (*b*).

Incomplete suppression of light diffraction at n_{rel} = 1 immediately at the interface is seemingly due to the influence, upon the deflected rays, of the screen material atoms, which are not only in the interface but in a layer of some thickness and for which $n_{rel} \neq 1$ due to the presence of the intermediate layer. Based on this, the screens with the lowest Δn in the intermediate layer should suppress the diffraction at $n_{rel.i}$ = 1 most strongly.

When n_{rel} decreases from 1.0054 to 1.0009 that corresponds to presence of pure benzyl alcohol in the cell, the plate at the interface becomes progressively less optically dense medium. As a consequence of the increase of the difference ($n_{rel.i.}$ − 1) the suppression of the deflection efficiency of edge rays *2* changes to its amplification resulting in the growth of the diffraction pattern contrast already at n_{rel} = 1.0048. Occurring in this case refraction decreases the deflection of light in the intermediate layer thus leading to a decrease of the light intensity within the shadow from the screen. Hence, the highest light intensity at the geometrical boundary of the shadow indicates the absence of refraction at the interface and equality of n_{rel} to unity here.

With the further increase of n of the liquid by solving α-bromine naphthalene (n_D = 1.6582) in the benzyl alcohol, the increasing refraction overcomes the influence of the intermediate layer forcing the refracted beams to propagate into the region of the diffraction pattern.

In the case of small n_{rel} a part of these rays have the path-length difference $\Delta \ll 0.5\lambda$ relative to rays *2* and, hence, sharply enhances the contrast of the diffraction pattern by interfering with the rays *1*. At the further increase of n of the liquid the refracted rays gradually go beyond the zone of rays *1* propagation, due to the growth of refraction angles, and cease to influence on the contrast of the diffraction pattern formed by the rays *1* and *2*. As a result, it decreases but yet remains high because $n_{rel.i}$ takes values higher than unity.

The suppression of light diffraction revealed is no way related to the partial transparency of the IKS3 plate near the edge *a*, since it occurs under conditions when the rays, refracted to the optically more dense plate, propagate along the direction different from the diffraction pattern and is the highest in the absence of refraction.

This is also confirmed by significant suppression of the diffraction pattern from a plate SS8-glass placed into dimethyl phthalate with small K_λ in comparison with that of the IKS3 plate.

The discussed facts of light diffraction suppression make up another evidence of the fictitiousness of the Fresnel secondary waves and show the way to increase the resolving power of optical instruments.

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