QUANTITATIVE DESCRIPTION OF LIGHT DIFFRACTION AT A SLIT (YOUNG'S REPRESENTATION)

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This paper presents formulas which have been derived on the basis of Young's representation and new data on the edge wave, which relate the intensity distribution of the diffraction pattern from a slit to the light intensity in the image plane with no slit and to the parameters of the diffraction experiment.

A comparison is made of the intensity of the diffraction pattern calculated using these formulas with the experimental values and the values calculated using the Fresnel formulas.

In three recent papers[1–3] in this journal I presented new facts concerning the characteristics of the edge wave and demonstrated on this basis that the diffraction pattern produced by a screen results from interference between the edge and the incident waves. In this case the diffraction distribution outside the projection of the slit must result from interference between the edge waves propagating from the two screens opposite each other, which form the slit. I will now demonstrate that this is indeed the case.

Figure 1 schematically shows a cylindrical wave diffracted by a slit S_2. Here l is the distance from the linear light source (slit S_1 of width t_0 = 60 μm, illuminated by a parallel ray of green light with wavelength λ = 0.53 μm) to S_2; L is the distance from the slit S_2 to the plane in which the diffraction distribution is scanned by the slit S_3; H_1, H_2, and h are, respectively, the distances from the light bands to the edge of the geometric shadow and to the ray propagation axis.

As should be obvious, the positions of the bands in the diffraction pattern are determined by the path difference Δ between the edge rays *1* and *2*. Since ray *2*, which deviates to the side from the edge of the slit, at this moment experiences a forward phase shift of 0.69π (it propagates from the slit edge), while ray *1*, deviating into the shadow zone, acquires a backward phase shift of 0.31π (see Ref. 1), ray *2* appears to be ahead of ray *1* by π (equivalently, $\lambda/2$) from the very start. Therefore, $\Delta = (\Delta_g - \lambda/2) = (Ht/L - \lambda/2) = k\lambda/2$, where Δ_g is the geometric path difference. Hence $h = (k + 1)\lambda L/t$. For k = 2, 4, 6 ..., rays *1* and *2* meet after accumulating a phase difference Δ equivalent to an integer number of wavelengths λ and produce illumination maxima. For k = 1, 3, 5, ..., illumination minima are produced.

Because of the existence of an initial path difference between the diaphragmed rays $h_{\min1} = \lambda L/t = (h_{\min2} - h_{\min1})$, so that the central maximum is twice as broad as the side ones.

If we take k to be the number of half-waves in Δ_g, then

$$h = k\lambda L/2t \tag{1}$$

and k = 3, 5, 7, ...correspond to the maxima, and k = 2, 4, 6, ... — to the minima in the intensity distribution. This formula differs somewhat from the distribution found in the experiment, as indicated, for example, by the data in Table I, which characterize the diffraction of light from a slit 95.2 μm wide. In this table $h_{\exp}$ are the experimental values of h; t_{eff} is the effective slit width, $t_{eff} = k\lambda L/2h_{\exp}$; Δt is the difference between the actual (t_{act}) and the effective (t_{eff}) slit widths; h_{cal} are the calculated distances to the bands; $h_{cal} = k\lambda L / 2\overline{t_{eff}}$ where $\overline{t_{eff}}$ is the average value of t_{eff}, found from the bands $h_{\min2}$ through $h_{\max4}$, the latter extrema corresponding to the range of slow decay of the edge wave.[1] In the considered case we have t_{eff} = 91.3 μm, i.e., it is 4 μm less than t_{act}. It may be concluded from act this result that light rays producing bands of orders higher than $\max_2$ diffract at a distance of approximately 2 μm away from the edge of the slit.

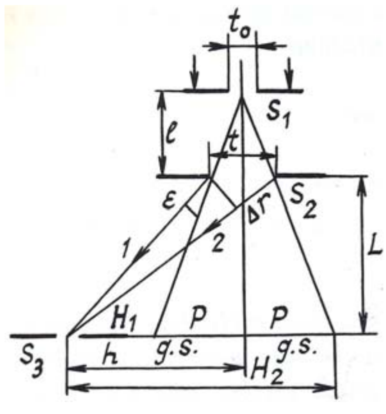

FIG. 1. Block diagram of a cylindrical wave incident on the slit.

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As can be seen from Table I, within the margin of error of our measurements the values h_{exp} are approximately equal to h_{cal} for every band except max_2, where $\Delta h = (h - h_{cal})$ is significant. The problem is that due to the rapid decay of the edge ray intensities around the position of max_2, it is displaced toward the diffraction pattern axis from its computed position by such a distance, that the increase in the intensity of the interfering edge ray is compensated by its diminution due to larger phase differences.

In contrast to max_2, min_1 tends to shift from its computed position away from the distribution axis. This shift continues until the decay in the overall intensity of the interfering rays, due to the decreasing relative difference between H_1 and H_2, is compensated by an increase in that same intensity. The latter effect is due to the growing deviation of the phase shift from its optimal value. The displacement of min_1 is less spectacular than that of max_2, since the overall intensity of the former due to incomplete extinction of rays *1* and *2*, which in turn is due to the inequality of H_1 and H_2, is low, and the decrease of that intensity at higher h is therefore already suppressed when the phase differences are quite small.

TABLE I.

Band	h_{exp}, mm	t_{eff}, μm	Δt, μm	h_{cal}, mm	$\Delta h_{exp.c}$, μm
min_1	0.665	89.3	5.9	0.650	15
max_2	0.925	96.3	-1.1	0.975	-50
min_2	1.312	90.5	4.7	1.300	12
max_3	1.612	92	3.2	1.625	-13
min_3	1.962	90.8	4.4	1.950	12
max_4	2.260	91.9	3.3	2.275	-15

TABLE II.

Band	h_{exp}, mm	t_{eff}, μm	Δt, μm	h_{cal}, mm	$\Delta h_{exp.c}$, μm	$\overline{t_{eff}}$, μm
min_1	0.840	137.2	9.8	0.812	28	—
max_2	1.170	147.8	-0.8	1.218	-52	
min_2	1.640	140.6	6.4	1.624	16	
max_3	2.010	143.4	3.6	2.029	-19	
min_3	2.450	141.2	5.8	2.435	15	
max_4	2.830	142.6	4.4	2.841	-11	142
min_4	3.250	142	5	3.247	3	
max_5	3.659	142.1	4.9	3.653	-3	

TABLE III.

Band	h_{exp}, mm	d_{eff}, μm	Δd, μm	h_{cal}, mm	$\Delta h_{exp.c}$, μm	$\overline{d_{eff}}$, μm
min_1	0.690	64	3	0.676	14	—
max_2	0.952	69.5	8.3	1.014	-62	
min_2	1.375	64.1	3.1	1.353	22	65.2
max_3	1.660	66.4	5.4	1.691	-31	

In principle, the above shift embraces all the bands, but as the band order increases, the shift should become less and less noticeable.

The considered features are also supported by the data from Table II, which characterize the diffraction of a plane wave at a slit $t_{act} = 147$ μm ($L = 217.5$ μm).

If a cylindrical wave is diffracted by a wire of actual diameter $d_{act} = 61$ μm (see Fig. 2, $\lambda = 83.2$ μm), the edge rays *1* and *2* are deviated by this wire. As a result, the wire's inferred average diameter, $\bar{d}$, found from h_{exp}, min_2, and max_3, exceeds its actual diameter by 4.2 μm (see Table III).

The disagreement of $\overline{t_{eff}}$ and $\bar{d}$ with t_{act} and d_{act} gives an additional proof of the existence above the surface of bodies of a zone in which a light ray entering it is deviated from its initial direction.[4–7]

If this approach is justified, the band intensity in the diffraction pattern J should be given by the dependence $J_{act} = A/H^2$ formulated in Ref. 1, which characterizes the dependence of the intensity distribution J_{act} in the edge wave on the distance H from the geometric shadow. The value of A should be constant for bands of different orders. According to Fig. 1,

$$J_{act1} = \frac{A}{H_1^2} = \frac{A}{(h-P)^2}, \quad J_{act2} = \frac{A}{(h+P)^2},$$

$$P = \frac{t\,(l+L)}{2l}.$$

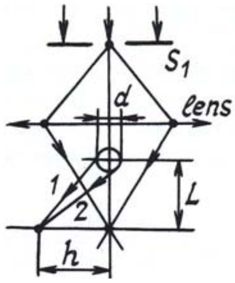

FIG. 2. Light diffraction by a wire.

The amplitudes of the edge waves are then equal to

$$a_1 = \frac{\sqrt{A}}{h-P} = \frac{2l\sqrt{A}}{2lh - t(l+L)},$$

$$a_2 = \frac{\sqrt{A}}{h+P} = \frac{2l\sqrt{A}}{2lh + t(l+L)}.$$

Due to the finite width of the slit S_1, there will be a spread in the value of P equal to $\Delta P = \pm\frac{t_0 L}{2l}$, thus introducing errors into the amplitude values. For the diffraction pattern maxima we have

$$a_{max} = a_1 + a_2 = \frac{8l^2\sqrt{A}\,h}{(2lh)^2 - [t(l+L)]^2},$$

$$J_{max} = a^2_{max} = \frac{64h^2l^4A}{\{(2lh)^2 - [t(l+L)]^2\}^2},$$

$$A_{(max)} = \frac{J_{max}\{(2lh)^2 - [t(l+L)]^2\}^2}{64h^2l^4} =$$

$$= \frac{J_{max}[h^2 - 0.25(t + tL/l)^2]^2}{4h^2} =$$

$$= 0.25J_{max}\,[h^2 - 0.5(t + tL/l)^2]. \quad (2)$$

At the same time, according to Eqs. (2) (see Ref. 2), we have for the cylindrical wave $A = \frac{0.02046\cdot\lambda L(L+l)J_{inc}}{l}$. Here J_{inc} is the incident ray intensity in the diffraction plane (the plane in which the diffraction pattern is scanned) at the edges of the geometric shadow if the slit S_2 is displaced from the ray.

Hence,

$$J_{max} = \frac{0.08184\lambda L(L+l)J_{inc}}{l[h^2 - 0.5(t + tL/l)^2]} =$$

$$= \frac{0.32736\lambda L(L+l)t^2J_{inc}}{l[(k\lambda L)^2 - 2t^4(1 + L/l)^2]}, \quad (3)$$

where $h = h_{cal}$, $t = \overline{t_{eff}}$ or $t_{act} - 4$ μm, and $2t^4(1 + L/l)^2 \ll (k\lambda L)^2$. For example, for $t = 0.155$ μm, $k = 3$, $L = 189$ μm, and $l = 100$ mm, the first expression is 9.4 times less than the second. Then the intensities of the maxima in the diffraction pattern produced by the slit S_2 are roughly proportional to the squared width of the latter. At first glance, this result should points to the dependence of J in the bands on the whole open part of the wavefront. However, as is clear from the above reasoning, this is not the case.

We have for the slit-generated diffraction minima

$$a_{min} = (a_1 - a_2) = \frac{4l\sqrt{A}\,[t(l+L)]}{(2lh)^2 - [t(l+L)]^2},$$

$$J_{min} = \frac{16l^2[t(l+L)]^2A}{\{(2lh)^2 - [t(l+L)]^2\}^2}.$$

Therefore

$$A_{(min)} = \frac{J_{min}\{(2lh)^2 - [t(l+L)]^2\}^2}{16l^2[t(l+L)]^2} =$$

$$= \frac{J_{min}[h^2 - 0.25(t + tL/l)^2]^2}{(t + tL/l)^2}. \quad (4)$$

Solving Eqs. (4) and (2) together,[2] we find

$$J_{min} = \frac{0.02046\lambda L(L+l)(t + tL/l)^2J_{inc}}{l[h^2 - 0.25(t + tL/l)^2]^2} =$$

$$= \frac{0.02046\lambda L(L+l)(t + tL/l)^2J_{inc}}{l[k^2(\lambda L/2t)^2 - 0.25(t + tL/l)^2]^2}. \quad (5)$$

It can be seen that the band intensities J_{cal} computed from relations (3) and (5) agree with the experimental values J_{exp}, and that A is constant for bands of various orders of diffraction. The data from Table IV, which describes the diffraction of a cylindrical wave at a slit $t_{act} = 159$ μm ($L = 189$ μm, $I = 100$ mm, $\overline{t_{eff}} = 155.2$ μm, as found from t_{eff} for min_2 through min_4 $J_{cal} = 1030$ rel. units), testify to this fact. The value J'_{exp} in this table gives the intensity at h_{cal}.

Table V gives the values of A found from J_{max2} at one and the same J_{cal} for various slit widths. As can be seen from the table, within the measurement accuracy margin the value of A remains constant for various t. This circumstance shows that the diffracted flux does not depend on the slit width (obviously, this is true for not too narrow slits). It can be easily understood if we recall that the total flux is produced by the rays not from the entire wavefront covering the overall slit width, but from the narrow areas around its edges.

TABLE IV.

Band	h_{exp}, mm	h_{cal}, mm	J_{exp}	J'_{exp}	J_{cal}	A
min_1	0.667	0.645	9.5	10	9.2	6.65
max_2	0.916	0.968	33	29.7	29.2	6.2
min_2	1.310	1.291	0.6	0.65	0.47	—
max_3	1.581	1.614	10	10	9.75	6.25
min_3	1.946	1.936	0.15	0.15	—	—
max_4	2.246	2.259	5	5	4.9	6.25
min_4	2.600	2.582	0.15	0.15	—	—

The latter statement is also supported by the coincidence of the intensities of the maxima plotted vs h for various slit widths.

TABLE V.

t_{act}, μm	A
159	6.2
117	6.4
79	6
39	6.5

The adequacy of the obtained relations and the constancy of A are also illustrated by Table VI, which contain data on the diffraction of a cylindrical wave by a slit t_{act} = 95.2 μm, for l = 36.2 mm, L = 112 mm, $\overline{t_{eff}}$ =91.6 μm, and J_{inc} = 1271 rel. units.

For a plane wave ($l = \infty$) relations (2), (4), (3), and (5) become

$$A_{(max)} = 0.25 J_{max}\left(h^2 - 0.5t^2\right), \tag{6}$$

$$A_{(min)} = \frac{J_{min}\left(h^2 - 0.25t^2\right)^2}{t^2}, \tag{7}$$

$$J_{max} = \frac{0.08184\lambda L J_{inc}}{h^2 - 0.5t^2} = \frac{0.32736\lambda L t^2 J_{inc}}{\left(k\lambda L\right)^2 - 2t^4}, \tag{8}$$

$$J_{min} = \frac{0.02046\lambda L t^2 J_{inc}}{\left(h^2 - 0.25t^2\right)^2} = \frac{0.08184\lambda L t^4 J_{inc}}{\left[\left(k\lambda L\right)^2 - t^4\right]^2}. \tag{9}$$

Tables VII and VIII demonstrate that under these conditions the value of A is constant, and the computational results from formulas (8) and(9) and experiment mutually agree.

The values of A in Table IX, found from the J_{max2} values for different slit widths for J_{inc} = const (L = 99.5 mm) demonstrate that even for a plane wave the value of A still remains independent of t.

To derive a relation giving the values of J in the diffraction pattern J_{act} for arbitrary $h > p$ and a cylindrical wave, we employ the addition rule for adding coherent oscillations

$$J_{act} = J_{act1} + J_{act2} + 2\sqrt{J_{act1}J_{act2}}\cos\psi, \tag{10}$$

where ψ is the phase difference between the first and the second rays (see Fig. 1). Substituting the values of A from formula (2) (see Ref. 2) into the expressions for J and J_{act1} and J_{act2} (see above) together with P we find that

$$J_{act1} = \frac{0.02046\lambda L l(L + l)J_{inc}}{[hl - 0.5(L + l)]^2}, \tag{11}$$

$$J_{act2} = \frac{0.02046\lambda L l(L + l)J_{inc}}{[hl + 0.5(L + l)]^2}, \tag{12}$$

where $t = \overline{t_{eff}}$ or $t_{act} - 4$ μm. Since the path difference from ray *1* to ray *2* is equal to $\frac{2ht - \lambda L}{2L}$, we obtain

$$\psi = 2\pi\frac{(2ht - \lambda L)}{2\lambda L} = \frac{(2ht - \lambda L)\pi}{\lambda L}. \tag{13}$$

TABLE VI.

Band	h_{exp}, mm	h_{cal}, mm	J_{exp}	J'_{exp}	J_{cal}	A
min_1	0.655	0.628	7.2	8	6.9	—
max_2	0.915	0.972	30.5	29	28.9	6.33
max_3	1.625	1.620	10.5	10	9.9	6.32
max_4	2.265	2.268	6	5.26	5	6.67

TABLE VII.

t_{act} = 184 μm, $\overline{t_{eff}}$ = 180.3 μm, L = 130.3 mm, J_{inc} = 2560 r.u.						
Band	h_{exp}, mm	h_{cal}, mm	J_{exp}	J'_{exp}	J_{cal}	A
min_1	0.390	0.383	6.5	6.8	6.1	4
max_2	0.550	0.575	47.5	47.5	46	3.74
max_3	0.945	0.958	16.7	16.5	16	3.72
max_4	1.343	1.341	8.5	8.5	8.1	3.79
max_5	1.732	1.724	5	5.1	4.9	3.77
max_6	2.120	2.107	3	3.25	3.3	3.53

TABLE VIII.

t_{act} = 48 μm, $\overline{t_{eff}}$ = 44 μm, L = 99.5 mm, J_{inc} = 7132 rel.unit						
Band	h_{exp}, mm	h_{cal}, mm	J_{exp}	J'_{exp}	J_{cal}	A
max_2	1.720	1.798	10	10	9.53	8.14
max_3	2.980	2.997	3.55	3.55	3.43	8
max_4	4.310	4.195	1.8	1.83	1.75	8.03

TABLE IX.

t_{act}, μm	A
48	4
98	3.7
184	3.75

Replacing J_{act1}, J_{act2}, and ψ in formula (10) by their values from formulas (11), (12), and (13), we may, after some rather simple transformations, express J_{act} in terms of J_{inc}, λ, and the parameters of the diffraction scheme:

$$J_{act} = \frac{0.04092\lambda L(L/l + 1)J_{inc}}{h^2 - 0.25t^2(L/l + 1)^2}\left[\frac{h^2 + 0.25t^2(L/l + 1)^2}{h^2 - 0.25t^2(L/l + 1)^2} + \cos\frac{(2ht - \lambda L)\pi}{\lambda L}\right], \qquad (14)$$

where $t = \overline{t_{eff}}$ or $t_{act} - 4$ μm. Since $l = \infty$ for the plane incident wave, formula (14) simplifies to yield

$$J_{act} = \frac{0.04092\lambda L J_{inc}}{h^2 - 0.25t^2}\left[\frac{h^2 + 0.25t^2}{h^2 - 0.25t^2} + \cos\frac{(2ht - \lambda L)\pi}{\lambda L}\right]. \qquad (15)$$

Let us compare the computational results from the above formulas with the experimentally obtained values (Tables X–XII, $\varepsilon = [(h - P)/L] \cdot 57.3°$). It follows from the tables that the disagreement between J_{exp} and J_{act} starts from approximately $\varepsilon < 0.085°$, i.e., from the moment the inverse proportionality between the edge wave amplitude and the deviation angle of the diffracted ray ceases to be valid.[2] Sometimes during diffraction of a cylindrical wave by a slit the value of J may become different from the computed value for the sides of the maxima. Moreover, if the value of J becomes larger (smaller) than the corresponding value of J_{act} in the remote diffraction band wings, the corresponding pattern in the near band wing becomes exactly the opposite. The reason for this interdependence may be understood from Fig. 3. It can be seen that the diffraction pattern produced by the slit S_2 is essentially a sum of patterns produced by the sources x and y of rays diffracted by the edges of S_1. The overall pattern from source x is then shifted away from the scheme axis with respect to the pattern that would have been observed if we had accounted for the path difference between rays *1'* and *2'* only, and which would have resulted from the initial phase difference of π not only between rays *1'* and *2'* but also between rays *1* and *2* preceeding the former, and due to the headstart ray *2* has over ray *1* (by $(0.5\lambda - tt_0/l)$).

TABLE X.

t_{act}=159 μm, $\overline{t_{eff}}$=154.8 μm, l=100 mm, L=189 mm, J_{inc}=414.5 r.u.						
Band	h, mm	J_{exp}	Ψ	cosΨ	J_{act}	ε^0
	0.3	153	11°10′	0.9811	585	—
	0.4	80	44°53′	0.7056	119.5	0.053
	0.5	32	101°24′	-0.1976	32.5	0.083
	0.6	7.5	157°41′	-0.8452	7.7	0.113
min_1	0.7	4.3	213°58′	-0.8293	4.5	0.144
	0.8	9.5	270°15′	0.0043	9.8	—
max_2	0.9	12.5	326°52′	0.8341	12.7	—
	1	11	382°48′	0.9218	10.5	—
	1.1	5.8	439°5′	0.1894	5.4	—
	1.2	1.9	495°22′	-0.5788	1.8	—
min_2	1.3	0.27	551°39′	-0.9794	0.25	—
	1.4	1.6	607°55′	-0.3759	1.7	—
	1.5	3.4	664°12′	0.5621	3.6	—
max_3	1.6	4.1	720°29′	1	4	—
	1.7	3.1	776°46′	0.5481	3	—

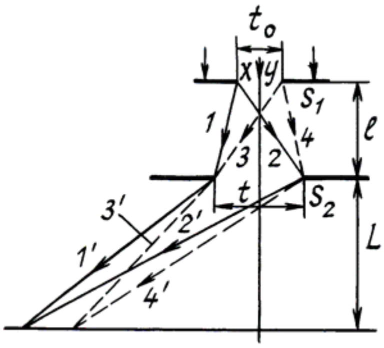

FIG. 3. Block diagram explaining the reason for the redistribution of the light intensity within the bands of the diffraction picture of the slit from the far to the near sides, and vice versa

Since ray *4* lags in its phase behind ray *3* by the same margin, the diffraction pattern produced by rays *3'* and *4'*, which derive from rays 3 and *4*, is shifted toward the scheme axis. Consider the case in which the intensities of x and y differ because of the inhomogeneous intensity distribution in the parallel ray incident upon the slit. It is easy to see, taking the above into account, that the value of J to the left of the maxima would be either amplified or suppressed in comparison with the case of constant light intensity over the slit width S_1, and suppressed (amplified) — to the right of them.

If the intensity of the light incident upon the slit S_2 is inhomogeneous at its edges, which is the case, for example, when S_2 is asymmetrical with respect to S_1, and the width of the central maximum of S_1 is comparable to the width of S_2, then the effect of interference of rays *1*, *2* (see Fig. 1) and of rays *1'*, *2'*, *3'*, and *4'* (Fig. 3) will be weakened. As a result, there appears a background decreasing the band contrast.

According to Fresnel[8] the intensity of the slit diffraction is equal to $J_F = C_F^2 + S_F^2$, where

$$C_F = \int_{v_1}^{v_2} \cos\left(\frac{1}{2}\pi v^2\right) dv \quad \text{and} \quad S_F = \int_{v_1}^{v_2} \sin\left(\frac{1}{2}\pi v^2\right) dv$$

are the Fresnel integrals.

When a plane wave diffracts off a screen with a sharp straight edge (Fig. 4), the parameter v is expressed as $v = \sqrt{2/\lambda L}$ (Ref. 9). At the same time, the geometric path difference between rays *1* and *2*, propagating from the edge A to some point Q of the diffraction pattern and to the wave pole B

respectively, is equal to $\Delta_g = h^2/2L = k\lambda/2$. Hence $h\sqrt{2/\lambda L} = \sqrt{2k}$, i.e., the value of v is equal to the square root of the number of wavelengths which fit into Δ_g. Based on the above, it is quite simple to find the values of v_1 and v_2 when a plane wave diffracts on a slit. They are equal, respectively, to

$$\sqrt{2/\lambda L}\ (h - 0.5t) \quad \text{and} \quad \sqrt{2/\lambda L}\ (h + 0.5t).$$

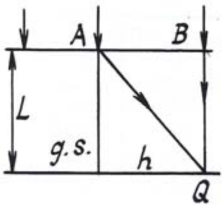

FIG. 4. Diffraction of a plane wave by a screen with a straight edge.

TABLE XI.

t_{act} = 79 μm, t_{eff} = 75 μm, L = 189 mm, l = 100 mm, J_{inc} = 1969 r.u

Band	h, mm	J_{exp}	Ψ	cosΨ	J_{act}	ε^0
	0.2	284	-124 57′	-0.5729	1101	—
	0.3	260	-91°41′	-0.0294	386	0.057
	0.4	228	-69°53′	0.088	238	0.088
	0.5	190	-42°21′	0.7392	181	0.118
	0.6	142	-14°50′	0.9667	137	0.148
	0.7	105	12°42′	0.9756	99	0.179
	0.8	69	40°14′	0.7634	67	0.209
	0.9	43	67°46′	0.3784	41.2	—
	1	22.4	95°18′	-0.0923	22	—
	1.1	10	122°49′	-0.5419	9.3	—
	1.2	2.8	150°21′	-0.869	2.4	—
	1.3	0.6	173°53′	-0.9993	0.22	—
min_1	1.35	0.8	191°39′	-0.9794	0.44	—
	1.4	0.8	205°25′	-0.964	0.6	—
	1.5	4	232°56′	-0.6027	4.2	—
	1.6	7.2	260 28′	-0.1656	7.7	—
	1.7	9.8	288°	0.309	10.7	—
	1.8	11.8	315°32′	0.7137	12.4	—
	1.9	12.2	343°3′	0.9565	12.7	—
max_2	1.95	12.2	356°49′	0.9985	12.3	—
	2	12.2	370°35′	0.983	11.64	—
	2.1	10.4	398°7′	0.7867	9.5	—
	2.2	7.4	425°39′	0.4123	6.84	—
	2.3	4.8	453°10′	-0.0552	4.2	—
	2.4	2.4	480°42′	-0.5111	2	—
	2.5	0.8	508°14′	-0.8502	0.58	—
min_2	2.6	0.1	535°46′	-0.9973	0.02	—
	2.7	0.4	563°17′	-0.9185	0.36	—
	2.8	1.2	590°49′	-0.6318	1.1	—
	2.9	2.2	618°21′	-0.2019	2.2	—
	3	3.5	645 53′	0.2736	3.3	—
	3.1	3.9	673°24′	0.6871	4.1	—
max_3	3.25	4.4	714°42′	0.9958	4.4	—
	3.4	3.8	756°	0.809	3.7	—

TABLE XII.

t_{act} = 48 μm, $\overline{t_{eff}}$ = 44 μm, L = 99.5 mm, l = ∞, J_{inc} = 7132 r.u.						
Band	h_{exp}, mm	ψ	$\cos\psi$	J_{exp}	J_{act}	ε^0
	0.06	-161°59′	-0.951	235	1775	—
	0.16	-131°56′	-0.6682	220.3	227	0.0795
	0.26	-101°54′	-0.2062	189.5	185.4	0.136
	0.36	-71°52′	0.3112	159.5	157.2	—
	0.46	-41°50′	0.7451	125.5	127.6	—
	0.56	-11°48′	0.9788	95	97.4	—
	0.66	-18°15′	0.9497	67.5	69	—
	0.76	48°17′	0.6655	45	44.5	—
	0.86	78°19′	0.2025	26.5	25.1	—
	0.96	108°21′	-0.3148	12.25	11.6	—
	1.06	138°24′	-0.7478	3.75	3.55	—
	1.16	168°26′	-0.9797	0.8	0.24	—
$\min_1$	1.2	180°27′	-1	0.75	0.01	—
	1.26	198°28′	-0.9485	0.85	0.5	—
	1.36	228°30′	-0.6626	3.25	2.8	—
	1.46	258°32′	-0.1988	5.8	5.8	—
	1.56	288°35′	0.3187	8.7	8.4	—
	1.66	318°37′	0.7503	9.75	9.8	—
$\max_2$	1.72	336°38′	0.918	10	10	—
	1.8	360°4′	1	9.55	9.5	—

Table XIII compares the values of J_F computed for the diffraction pattern bands L = 130.3 mm, t_{act} = 184.3 μm, $\overline{t_{eff}}$ = 180.3 μm with the experimental intensities (see Table VII).

TABLE XIII.

Band	J'_{F1}	J'_{F1}/J'_{exp}	J'_{F2}	J'_{F2}/J_{exp}
$\min_1$	6.67	0.98	9.48	1.365
$\max_2$	56.3	1.186	61.22	1.289
$\min_2$	0.43	—	1.27	—
$\max_3$	19.85	1.203	20.34	1.233
$\max_4$	10.05	1.182	9.44	1.111
$\max_5$	6.06	1.188	5.27	1.033
$\max_6$	4.04	1.347	3.2	1.067

Here the values of J'_{F1} and J'_{F2} are the Fresnel reference band intensities, normalized to the value of J_{inc} (equal to 2560 rel. units), by the relations $J'_{F1} = J_{F1}J_{inc}/J_{Finc}$, $J'_{F2} = J_{F2}J_{inc}/J_{Finc}$. In these formulas J_{F1} and J_{F2} denote the intensities found using the Fresnel integrals10 for the values of $\overline{t_{eff}}$ and h_p, t_{act} and h; and J'_{Finc} is the intensity produced by a completely opened wavefront (according to Fresnel). The latter is equal to $\left(2\sqrt{0.5^2+0.5^2}\right)^2$ = 2, where 0.5 is the limiting value of the Fresnel integrals.

TABLE XIV.

Band	J'_{F1}	J'_{F1}/J'_{exp}	J'_{F2}	J'_{F2}/J_{exp}
$\min_1$	6.88	1	9.48	1.317
$\max_2$	35.3	1.221	40.1	1.315
$\min_2$	0.4	1.212	1.8	—
$\max_3$	12.23	1.235	10.87	1.035
$\max_4$	6.17	1.174	5.18	0.863

Consider a cylindrical wave diffracting at a slit (Fig. 1). Since $v = \sqrt{2k}$, and k is equal to the number of half periods which fit into the geometric path difference between the rays propagating from the source to the observation point via the wave pole and the slit edge, we have

$$v_1 = \left[h - \frac{t(l + L)}{2l}\right]\sqrt{\frac{2l}{\lambda L(l + L)}},$$

$$v_2 = \left[h + \frac{t(l + L)}{2l}\right]\sqrt{\frac{2l}{\lambda L(l + L)}}.$$

Applying these expressions, we may calculate the diffraction band intensities produced by the slit. The chosen experimental parameters were as follows: L = 112 mm, l = 36.2 mm, t_{act} = 95.2 μm, $\overline{t_{eff}}$ = 91.6 μm, and J_{inc} = 1271 rel. units (see

Table VI). The corresponding computational results are shown in Table XIV.

As can seen from Tables XIII and XIV, in contrast to J_{cal}, the values of J'_{F2} deviate significantly from the experimentally found intensities in low diffraction orders. However, for higher diffraction orders these differences gradually diminish.

REFERENCES

1. Yu.I. Terent'ev, Atm. Opt. **2**, No. 11, 970 (1989).
2. Yu.I. Terent'ev, Atm. Opt. **2**, No. 12, 975 (1989).
3. Yu.I. Terent'ev, Atm. Opt. **2**, No. 12, 1141 (1989).
4. Yu.I. Terent'ev, Izv. Vysch. Uchebn. Zaved. SSSR, Ser. Fiz., No 8, 48–54 (1977).
5. Yu.I. Terent'ev, Izv. Vysch. Uchebn. Zaved. SSSR, Ser. Fiz., No. 12, 55–58 (1987).
6. Yu.I. Terent'ev, Opt. Atm. **1**, 130–133 (1988).
7. Yu.I. Terent'ev, Atm. Opt. **1**,No. 2, 111–112 (1988).
8. R. Ditchburn, *Physical Optics* [Russian translation] (Nauka, Moscow, 1965), 631 pp.
9. S.E. Frish and A.V. Timoreva, *Course Of General Physics*, Vol. 3 (Gos. Izdat. Techn. Lit., Moscow, 1951).
10. G.T. Artamonov et al., *Tables of Fresnel Integrals*, ed. by V.A. Ditkin (Izdat. Akad. Nauk SSSR, Moscow, 1953).