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LIGHT REFLECTION FROM ROUGH SURFACES

by
V. K. Polyanskiy
V. P. Rvachev

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Translated from the Russian

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The effect of the scattering of polarized light by a dull dielectric surface has been studied. The zeroth diffraction approximation proves to be more detailed than does the ray-optics approximation. In such an approximation, we must repeatedly explain the fact of light depolarization and the dependence of polarization effects upon the scattering conditions and also the displacement of the maximum of the scattering curve for larger observation angles.

AUTHOR

There are at present two methods for studying the interaction of light with a rough interface between two media. The first (stricter) consists of mathematically studying the diffraction of plane waves by a rough interface. Using this method, Rayleigh (V. Strutt)[1] gave an approximate solution to the problem of plane-wave scattering by a sinusoidal surface for normal incidence. Later on, a method was developed by Andronov and Leontovich[2] and Antokol'skiy[3]; finally, articles by Brekhovskikh[4] described a solution to the problem of plane-wave scattering by a periodic surface for arbitrary angles of incidence, and gave the results of specific calculations for a sinusoidal and broken periodic (sawtooth) surface. Another method uses the fact that a rough surface can be represented as a set of microareas statistically distributed with respect to orientation, each of which reflects according to the laws of ray optics[5]. These representations are a basis for articles by Gershun and Popov[6], Ivanov and Toporets[7], Mullamaa[8], Gorodinskiy[9], and a number of others.

We should note that these two methods for solving a particular problem coincide at a very small number of points and are, in essence, developed independently. Of particular importance is an article by Isakovich[10] which is devoted to the problem of wave scattering by a totally reflecting statistically-rough surface. This is the main point of an article which is quite familiar to us which notes the tendency of two methods of investigating the optical properties of dull surfaces to converge.

The purpose of this article is to study the scattering properties of dull surfaces in polarized light and to explain some observed effects using light-diffraction representations in addition to those of ray optics. Here, we will restrict ourselves to considering the effects at the interface of isotropic transparent media.

1. The experimental device intended for measuring brightness is similar to the one described by Gershun and Popov[6] but has in addition

an interference light filter, polarizer, and analyzer. The FEU-19 photomultiplier is used to receive radiation; the signal generated by the photomultiplier is sent to the reference unit UF-206. The optical systems of the illuminator and receiver make it possible to assign aperture angles of 2° to 12' for the illuminating and recorded beams; this corresponds to the minimum solid angle $\omega = 1 \cdot 10^{-6}$ ster. In order to provide appropriate light fluxes, a high-power heater tube (K-30, 17 v, 170 w) was used as the light source, and was enclosed by a jacket cooled by circulating water. An interference light filter $\lambda = 550$ nm was used to monochromatize the light. The error in reading the orientations of the principal planes of the polarizer and analyzer did not exceed 20'; the error in reading the angles of incidence or observation was 10', while the sums of these angles were 2'. The specimens were placed on the stand of a goniometric circle. Figure 1 gives the principle of this device.
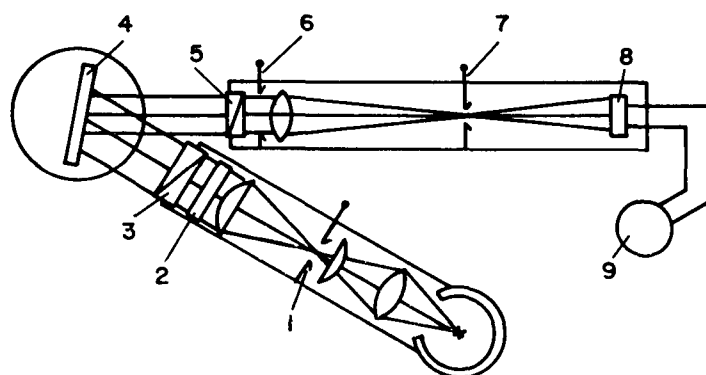
1 - Aperture Diaphragm
    of Illuminator
2 - Interference Light Filter
    (550 nm)
3 - Polarizer
4 - Object
5 - Analyzer

6 - Field Diaphragm
7 - Aperture Diaphragm
    of Receiver
8 - Photomultiplier
9 - Reference Device
    (Total Length of Optical
    System 2.3 m)

Figure 1. Optical Diagram of Device.

2. **Experimental Basis.** We shall consider a rough surface as being a set of statistically distributed microareas. We shall assume the incident light beam is parallel, monochromatic, and linearly polarized. The state of polarization of this beam will be described by the azimuthal angle φ between the direction of oscillation of the electric

vector and the plane of incidence. Observations will be made in a plane coinciding with the plane of incidence; the angles of incidence β and observation α are read off relative to the normal to the surface. The index of refraction n of the second medium relative to the first is assumed to be real and greater than unity. In accordance with the ray-optics approximation we shall assume that rays reflected from microareas oriented uniquely will propagate in every given direction. The normals of the microareas under consideration lie in the plane of incidence. The orientation of each microarea is determined by the angle γ between the normal to the surface and the normal to the microarea.

In the ray-optics approximation the effect of a set of identically oriented microareas is equivalent to the effect of one area having a corresponding magnitude and orientation. Rays reflected by different microareas are, in general, not coherent; the total intensity of the beam reflected in a given direction is determined as a sum of partial intensities.

If we assume that the reflected beam consists of a set of singly-reflected rays (i. e. , multiple reflections are not considered), then, as in the case of a polished surface, the reflected beam is plane-polarized but the plane of polarization is turned so that the azimuthal angle φ' between the plane of oscillation of the electric vector and the plane of observation is determined by the relationship

$$\operatorname{tg} \varphi' = - \frac{\cos\left(\dfrac{\alpha + \beta}{2} - r\right)}{\cos\left(\dfrac{\alpha + \beta}{2} + r\right)} \operatorname{tg} \varphi \, , \tag{1}$$

where r (angle of refraction) is determined by the Snell law $\sin(\alpha + \beta)/2$ = n sin r. In order to obtain (1) we must expand the electric vector in the incident beam into s- and p-components , use the Fresnel formulas for each of them, and find the ratio of these components in the reflected beam. We must set $\alpha = \beta$ for a polished surface.

If we let $\varphi = 45°$ in the incident beam, then the s- and p-components of the electric vector in the incident beam are the same; in this sense, the incident plane-polarized beam is equivalent to a beam of ordinary (unpolarized) light. Measurements using different types of analyzers corresponding to the transmission of electric vectors with azimuths 0, $\pi/2$, φ', $\varphi' \pm \pi/2$, all other conditions being equal, make it possible to obtain information as to the changes both ordinary beams and polarized beams undergo upon reflection. Thus, from the first pair of readings N_0 and $N_{\pi/2}$ (in view of the above-stipulated inherent equivalence

of the incident plane-polarized flux with azimuth $\varphi = 45°$ owing to the fact that the p- and s-components of the electric vector are equivalent) we obtain

$$P = \frac{N_0 - N_{\pi/2}}{N_0 + N_{\pi/2}}$$

for the degree of polarization of ordinary light when reflected from the surface under consideration. If the reflected beam is completely polarized the reading $N_{\varphi'\pm\pi/2}$ is zero. Since the beam is partially depolarized after reflection, $N_{\varphi'\pm\pi/2} \neq 0$. The degree of depolarization will be computed from the relationship

$$\Delta = 1 - \frac{N_{\varphi'} - N_{\varphi'\pm\pi/2}}{N_{\varphi'} + N_{\varphi'\pm\pi/2}} = \frac{2N_{\varphi'\pm\pi/2}}{N_{\varphi'} + N_{\varphi'\pm\pi/2}} = \frac{2N_{min}}{N_{min} + N_{max}}$$

The quantities P and Δ characterize the changes in beams of different types (ordinary and polarized) although the incident beams are plane-polarized in both cases. Under the above assumptions, it is not difficult to obtain the relationship

$$P = \frac{\cos^2\left(\frac{\alpha+\beta}{2} + r\right) - \cos^2\left(\frac{\alpha+\beta}{2} - r\right)}{\cos^2\left(\frac{\alpha+\beta}{2} + r\right) + \cos^2\left(\frac{\alpha+\beta}{2} - r\right)} = \frac{1 - tg^2\,\varphi'}{1 + tg^2\,\varphi'} \qquad (2)$$

for the degree of polarization.

This assumption must be satisfied in the same manner as in the assumption that the outer component of the reflected flux maintains the state of polarization of the incident flux[11]. In this case $\Delta = 0$.

3. Experimental Results. The selection of the object for experimental study was determined by the requirements that the inner component be absent,and that there be no ellipticity in the reflected beam. In other words, the object must only have an outer component and possess a real index of refraction. For this purpose , a plate of black glass with refractive index n = 1.515 was chosen (determined according to the Brewster angle) where one surface was polished and the other dulled mechanically (electrocorundum No. 240). By experimentally studying the structure and curve of brightness of the beam reflected by the polished surface of the specimen, we established that the imposed requirements are satisfied within the limits of experimental error.

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This agrees with Gorodinskiy's data[9]. In a beam mirror reflected by the polished surface the light becomes completely polarized and the orientation of the electric vector corresponds to expression (1). Relationship (2) is also well satisfied.

Figures 2 and 3, which give typical experimental curves, characterize the results of investigating the polarization characteristics of beams reflected from a dull surface.

1 - $\beta = 30°$ 4 - Polished Glass
2 - $\beta = 45°$ (Theoretical and Experimental)
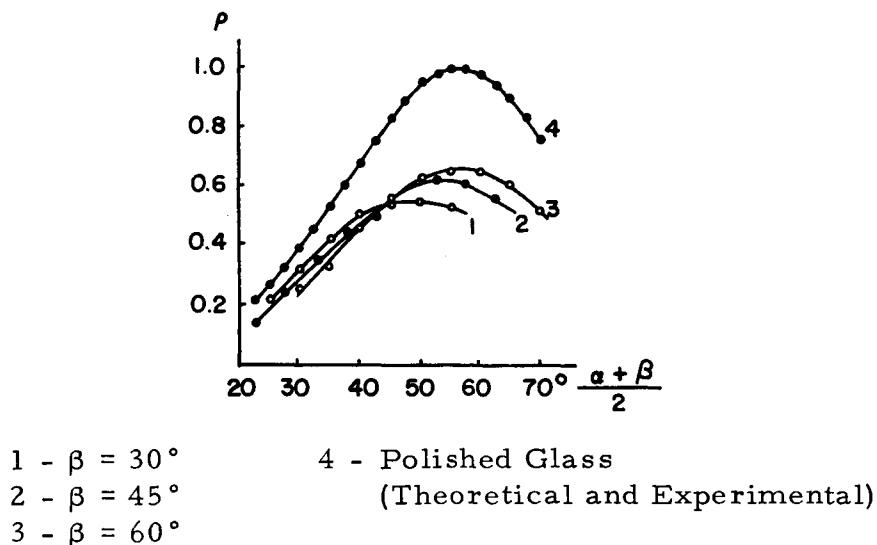3 - $\beta = 60°$

Figure 2. Degree of Polarization of a Light
Beam Reflected from a Dull Surface.

The results given in Figure 2 are also found to agree with Gorodinskiy's results[9] obtained in experiments using ordinary light. Our curves permit us to conclude that light polarization, upon reflection from a dull surface, depends considerably upon the angle of incidence β. When β decreases, the degree of polarization has a smaller maximum and the maximum is displaced in the direction of lower values for the half-sums of the angles of incidence and observation $(\alpha + \beta)/2$. When $(\alpha + \beta)/2$ is fixed and less than or about equal to 45°, polarization increases with a decrease in β; if $(\alpha + \beta)/2 \gtrsim 45°$, polarization decreases when β decreases.

The results given in Figure 3 characterize depolarization caused by reflection from a dull surface. Here, the polarization properties as a function of the angle of incidence prove to be much more clearly

$1 - \beta = 30°$ $3 - \beta = 60°$
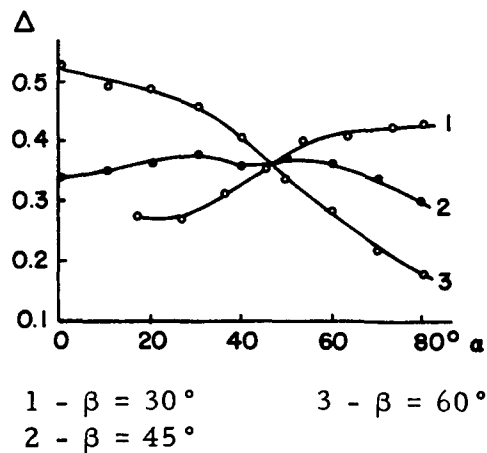$2 - \beta = 45°$

Figure 3. Depolarization of a
Light Beam Upon Reflection
from a Dull Surface.

defined. For small angles of incidence the polarization is relatively low but increases rapidly when the angle of observation increases. For large angles of incidence the polarization is great and decreases rapidly when the angle of observation increases. When $\beta = 45°$ the depolarization was almost constant for our experiment when the angle of observation changed.

As was the case for reflection from a dull surface, the electric-vector orientation predominating in a beam reflected from a dull surface is determined so accurately from Equation (1) that the measured angles are no different from those computed. Equation (2) which is very accurate for beams reflected from a dull surface yielded somewhat exaggerated results for this dull surface; the greater the surface roughness and the smaller the angle of incidence, the greater the deviation of the results from those calculated. The assumption as to the state of polarization remaining constant upon reflection is only weakly satisfied and the magnitude of the depolarized flux can prove greater than the polarized one.

4. Discussion of Experimental Results. The idea of representing the diffusion-reflected beam as a set of parallel beams mirror-reflected from microareas makes it possible to obtain satisfactory results when the polarization plane is rotated for reflection of a plane-polarized beam; it also makes it possible, at least qualitatively, to form an opinion as to the distribution function of the microareas with respect to direction[7,8].

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The presence of a depolarized component in the beam and its low (in comparison to that computed using the Fresnel formulas) polarization upon reflection from a dull surface is usually associated with the presence of rays which are reflected more than once. However, this explanation is not sufficient since, preceeding only from the ray-optics representations, we are often unable to explain such experimental facts as the deflection in the intensity maximum from the direction of mirror reflection toward larger angles of observation, the relatively high depolarization component in the reflected beam, and also a number of other effects. Thus, in order to explain the fact that the polarized and depolarized fluxes are roughly equivalent, we must assume on the basis of the concept of multiple reflection that the number of times multiple reflection occurs is at least 20-25 times greater than the number of times single reflection occurs. (For every reflection from the glass surface, which possesses, as is known, a reflection coefficient of the order of 4-5% and for equal angles of incidence and reflection ($\lesssim 50°$) the beam must attenuate by a factor of 20-25.) However, such an assumption contradicts Gershun's data[6] which deals with the distribution function of the direction of the microareas.

The effects which are observed when light is reflected from a dull surface can be explained in greater detail if we use diffraction representations (even when we restrict ourselves to the zeroth diffraction approximation).

Let us consider the interaction of a plane wave and an aperiodic uniform reflecting lattice. In other words, for the sake of simplicity, we shall assume that the dull surface consists of a set of plane bands with parallel adjacent edges. The bands are of different widths l and are tilted differently. The inclination of the bands is given by the angle γ. The bands under consideration are similar to the microareas; qualitatively, such a simplification for the object does not affect the results (however, it is necessary to introduce a correction (the form factor) for quantitative calculations). Figure 4, which shows one such band, also gives the notation which will be necessary below.

The intensity distribution in the diffraction pattern is determined by the path difference δ. Upon using ordinary methods to compute the path difference, we obtain, in our case,

$$\delta = 2l \cos \frac{\alpha + \beta}{2} \sin \left(\frac{\alpha - \beta}{2} - \gamma \right) . \tag{3}$$
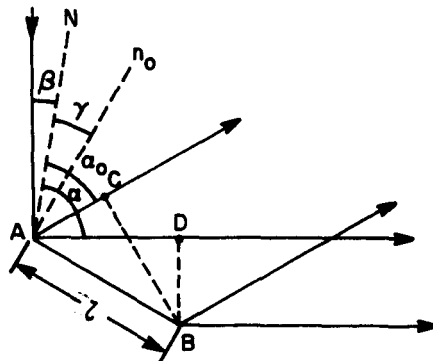
β - Angle of Incidence a_0 - Direction of Principal Maximum
α - Angle of Observation   Path Difference δ = AD-AC

Figure 4. Calculation of Reflection Allowing
for Diffraction Effects.

The path difference $\delta = 0$ for the direction of the principal (zeroth) diffraction maximum. It is clear from Figure 4 that this occurs when $a_0 = \beta + 2\gamma$ which is the same as the mirror-reflection condition.

Relationship (3) shows that the direction of the zeroth diffraction maxima, created by each individual microarea (principal part of the curve) is determined only by their orientation, i.e., the direction distribution function[5,6,7] $f(\gamma)$. The direction of propagation of the maxima of the first and higher orders is determined not only by the direction distribution function but also by the size distribution function.

In contrast to the ray-optics approximation the principal diffraction maximum proves to be blurred. Using relationship (3) to estimate the diffraction broadening of the reflected microarea of the pencil of rays allowing for the fact that the direction to the first minimum is determined by the condition $\delta = \lambda$ we arrive at the result

$$\Delta a \gtrsim \frac{\lambda}{2l} , \qquad (4)$$

where broadening increases with an increase in the angle of incidence β and the angle of inclination of the microarea γ.

In the case of oblique incidence the diffraction pattern proves to be asymmetric. In particular, the intensity distribution in the principle maximum (better termed principal beam) also proves to be asymmetric.

In fact, let us determine the directions $a_0 + 2\psi$ and $a_0 - 2\xi$ for which the path difference is the same in absolute value and opposite in sign. As is not difficult to see, the corresponding conditions can be written on the basis of (3) in the form

$$\cos\left(\frac{a_0 + \beta}{2} + \psi\right) \sin\psi = \cos\left(\frac{a_0 + \beta}{2} - \left|\xi\right|\right) \sin\left|\xi\right| . \qquad (5)$$

We can easily verify that the last equality is satisfied by nonzero values of ψ and ξ only when

$$\left|\psi\right| > \left|\xi\right| . \qquad (6)$$

Since the intensity in a given direction is determined (for ordinary light) by the path difference, we can conclude on the basis of relationships (5) and (6) that within the limits of each diffraction maximum when the angle of observation increases the intensity first increases rapidly (from zero to some maximum) and then drops more slowly to zero. If the maximum under consideration is represented in the form of a fringe on the band pattern, the fringe proves to be asymmetric -- turned in the direction of increasing angles of observation read off from the normal. (Note in passing that this statement also refers to the form of the spectral line found in diffraction spectral devices for oblique incidence.) Asymmetricity in the principal beams leads to asymmetricity in the curve. In fact, if two principal beams (two principal maxima) caused by diffraction from different microareas partially intersect, then assuming these beams are mutually incoherent, the total intensity is calculated as the sum of the intensities in each beam:

$$I(a) = I_1(a) + I_2(a) .$$

In such a case, the position of the resulting maximum is determined by the condition (Figure 5):

$$\frac{d}{da} I_1(a) = - \frac{d}{da} I_2(a) .$$

By extending such a consideration to an arbitrary number of beams we are led to the conclusion that the maximum of reflection must be shifted in the direction of larger angles of observation for oblique illumination of a dull glass. This was also observed experimentally. Note that such a shift in the maximum invariably leads to error in determining the distribution function of the microareas by familiar methods[7,8].
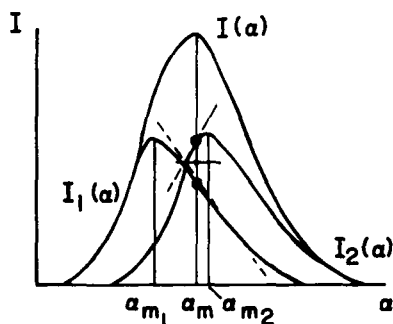
Figure 5. Illustration of the Shift
in Maximum for Addition
of Asymmetric Pulses.

If the incident beam is plane-polarized, it is natural to assume that a beam reflected from one microarea is polarized and characterized by the azimuth φ' in Equation (1).

If rays reflected from microareas oriented uniquely propagate in a direction determined by the angle of observation α and irradiation and observation are performed using strictly parallel beams, then, assuming there is no multiple reflection, the reflected beam becomes plane-polarized with varying azimuth.

The presence of multiple reflection involves some depolarization; however, the intensity contributed by multiple reflection can barely exceed 3-5% of the total flux.

The depolarization resulting from the finite dimensions of the angular aperture of the receiver system and illuminator system is negligibly small under our conditions since (see Section 1) the aperture angles lie within the limits of 12'-15' (the diameters of the diaphragms of the collimator and receiver are 0.8 mm and the focal lengths of the objectives are 300 mm).

In fact, the principal beams resulting from diffraction on the micro-areas with different orientations are propagated in the direction of observation. These beams are incoherent and are polarized in different planes. (For normal incidence on the microarea, the reflected beam retains the azimuth of the incident beam (45°); when the angle of incidence is very close to the Brewster angle the azimuth is 90°; for further increase, the azimuthal angle reaches 135°.)

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When the dimensions of the microareas are comparable with the wavelength of light we may find a good deal of beam overlapping. Thus, if $l \cos (\beta + \alpha)/2 \approx 5\lambda$ then in accordance with (3), the principal beams from the microareas propagate in the direction of observation and the normal to the microarea lies within the limits of 12°. The effect of beam overlapping is, in general, equivalent to an increase in the aperture of the observer system; therefore, it is an unnecessary precaution to attempt to reduce the aperture angle of the latter to less than 1°. Overlapping of the principal beams occurring as a result of diffraction on the microareas with different orientation and therefore characterized by different azimuths must lead to a partial depolarization of the resultant beam. This effect has also been observed experimentally.

Beam overlapping must be reduced when the effective dimensions of the microareas are increased, i.e., when the first factor in expression (3), $l \cos (\alpha + \beta)/2$, is larger or when the angle of incidence β is smaller. When there is little beam overlapping (diffraction maxima from different microareas) there is little depolarization. When β increases depolarization must increase. This effect has been observed experimentally and is shown in Figure 3 (for small α). An increase in the angle of incidence and a decrease in l results in conditions where the dull surface begins to introduce a mirror component[12,13]. In this case depolarization decreases with an increase in β. The appearance of this mirror effect can be explained by the features of the curves in Figure 3 for larger values of β and α. Under certain conditions, these effects compensate for one another; in our case this occurs when $\beta = 45°$.

A reduction in the dimensions of the surface microstructure (processing with finer abrasives) is accompanied by the appearance of partial coherence which leads to a reduction in surface depolarization and, in the long run, to mirror (coherent) reflection. The laws described by Gorodinskiy[9] explain this.

Thus, we can say that depolarization, upon reflection, is due not only to the presence of multiple reflection and finite aperture of the observer device but also (mainly) to diffraction by the surface microareas.

LITERATURE CITED

1. V. Strutt (Rayleigh), Teoriya zvuka (Theory of Sound), Pub. by AS USSR, Vol. II, Moscow, 1954.

2. A. A. Andronov, M. A. Leontovich, ZhRFKhO, 38, 485, 1926.

3. M. L. Antokol'skiy, DAN SSSR (Reports of the Acad. Sci., USSR), 62, 203, 1948.

4. L. M. Brekhovskikh, ZhETF (Journal of Experimental and Theoretical Physics), 23, 275, 289, 1952.

5. P. Bougner, Opticheskiy traktat o gradatsii sveta (Optical Treatise on Light Gradation), Pub. by AS USSR, Moscow, 1950.

6. A. A. Gershun, O. I. Popov, Transactions of the GOI (State Optical Institute) 24, No. 143, 3, 1955.

7. A. P. Ivanov, A. S. Toporets, ZhTF (Journal of Technical Physics), 26, 623, 631, 1956.

8. Yu. Mullamaa, Issled. po fizike atmosf. (Study of Atmospheric Physics), AS ESSR, 3, 5, 1962.

9. G. M. Gorodinskiy, Opt. i spektr. (Optics and Spectroscopy), 16, 112, 1964.

10. I. A. Isakovich, ZhETF, 23, 305, 1952.

11. A. S. Toporets, ZhETF, 20, 390, 1950.

12. A. S. Toporets, Opt. i spektr., 16, 102, 1964.

13. G. S. Landsberg, Optika (Optics), GTI, Moscow, 1957.

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The effect of the scattering of polarized light by a dull dielectric surface has been studied. The zeroth diffraction approximation proves to be more detailed than does the ray-optics approximation. In such an approximation, we must repeatedly explain the fact of light depolarization and the dependence of polarization effects upon the scattering conditions and also the displacement of the maximum of the scattering curve for larger observation angles.

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