# **Experiments with Polarized Light at Slit and Double -Slit**

Helmut Nieke

Abstract
Experiments at slit with varied polarized light show only at very narrow slit-widths and high diffraction-orders a noticeable influence. This is explained by Newton's demonstration of localization of bent light near the edge. The experiment by Fresnel is repeated where a double-slit with right and left circular polarized light in the single slits yields no interferences. This result was confirmed but with a polarizing-filter in front of the catch-up plane appeared the interference-figure of double-slit, whereat its fringes move by turning the filter. Therefore without polarizing-filter only a blurred figure is originated.

## I. Present results

Already in the time of Newton polarization was known (Iceland crystal) and therefore Newton [1] III query 26 supposed several sides of light. To explain the turning of plane of polarization Biot [2] introduced the theory of movable polarization. Accordingly the plane of polarization could be turned and rotated. Fresnel [3] tried to represent linear polarized light by two opposed circularly polarized waves. With a combination of two or three right- and left-rotating prism of quartz Fresnel could generate two opposite circularly polarized beams. Lang [4] and Cornu [5] showed that this is possible even with one 60°-prism optical axis parallel to the basis. With a telescope they could prove an angle-difference of 27". Thomson [6] tried to explain the stable position of polarization-plane with a rotating ether.

## II. The diffraction-figure of slit in polarized light

In experimental examinations of diffraction at slit with visible light is reported in accordance that the polarization of incident light has no or a trifling influence on diffraction-figures. Only in extreme cases was found partial polarized light as by Wien [7] who focused sun-light on an edge and observed in large shadow-side angles. This is differently in experiments with gratings. Here Hertz [8] found with wire-gratings of intervals about 1/50 $\lambda$ with a high-frequency radiation that intensity is higher if the E-Vector laid perpendicular to the direction of wires.
Bois [9] found the opposite behaviour with optical gratings with grating-intervals of 20 to 100 $\lambda$ , the direction parallel of grating-direction showed the highest intensity. With heat-radiation Bois a. Rubens [10] found a transition. Wolfson [11] gave a summary.

The radiation of a He-Ne-laser was focused over a rotator with a microscope objective on the illumination-slit demonstrating the influence of polarization of light in diffraction- figures of slit. An objective directed the light parallel and a behind standing precision-slit served as diffraction-slit. It was controlled that behind rotator and illumination-slit at turning the rotator in the middle of diffraction-figure of illumination-slit appear no change of intensity.

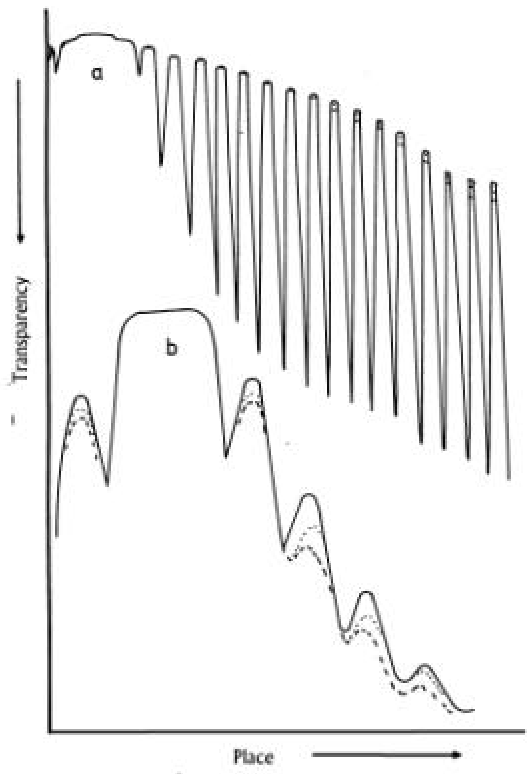


*Figure 1. Examples for influence of polarization of light in diffraction at slit. The light of a Ne-He-laser HNA 50 passed a rotator and was focused on the illumination-slit 0.05 mm slit-width. The with an objective f' = 35 cm parallel directed light strikes the diffraction-slit.*
*a: 1 mm slit-width in 1 m distance, b: 0.03 mm slit-width in 0.065 m distance.*

| | | |
|---|---|---|
| *Photometer-curves:* | _______ | *E-Vector parallel to slit,* |
| | ............. | *45° to slit,* |
| | - - - - - - | *perpendicular to slit.* |

Figure 1 shows some photometer-curves at different slit-widths and distances. In large slit-width only trifling and only by photometrical evaluation noticeable differences are found in sense of Bois [9]. In small slit-widths these differences become noticeable. So higher the order of diffraction-fringes and smaller slit-widths so greater becomes the influence of direction of polarization of incident light.

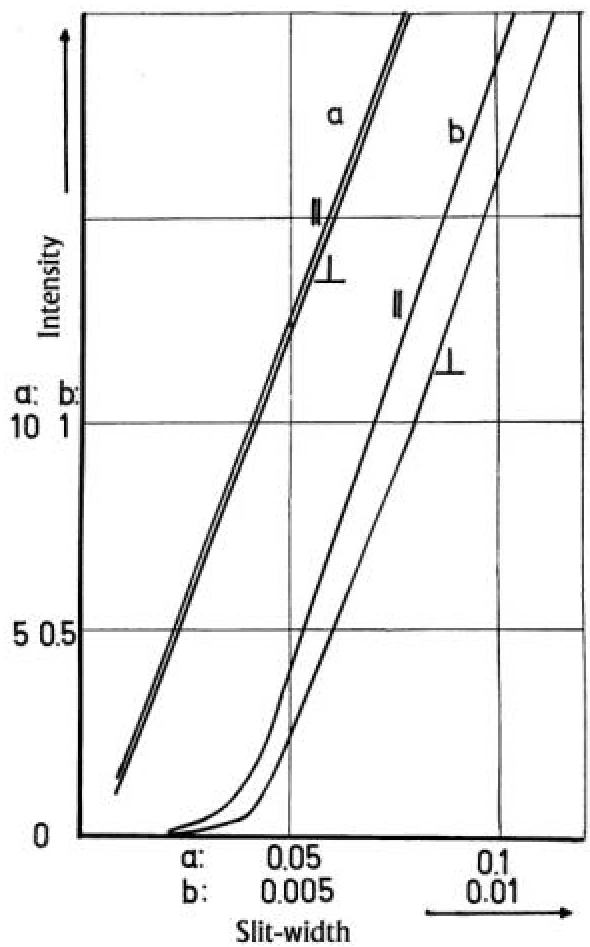


*Figure 2. Relative intensity in dependence of direction of polarization of incident light from a He-Ne-laser through a slit of variable slit-width light. Abszissa: slit-width a: 0.0.. .mm and b: 0.00.. mm;*
*Ordinate: Relative Intensity a: x 1 and b: x 0.1.*
*çç parallel to slit,*
*^ E-Vector perpendicular to slit.*

III. Dependence of total-intensity on direction of polarization

The enlarged radiation of a He-Ne laser behind a chopper and a rotator incident a precision-slit, the bevelled and blacken side to the light. Behind the plane-side of the slit stood, laid directly close, a secondary-electron multiplier, so that practically all the radiation, that passes the slit, could be registered by the multiplier. The current was amplified, phase-sensitive rectified and measured.

At small slit-widths the fixing of slit-width nought is a problem. Here was used the start of moving the slit-jaws as it was visible in incident light. In transmitted light one finds the slit-width nought in 0.001 to 0.002 mm.

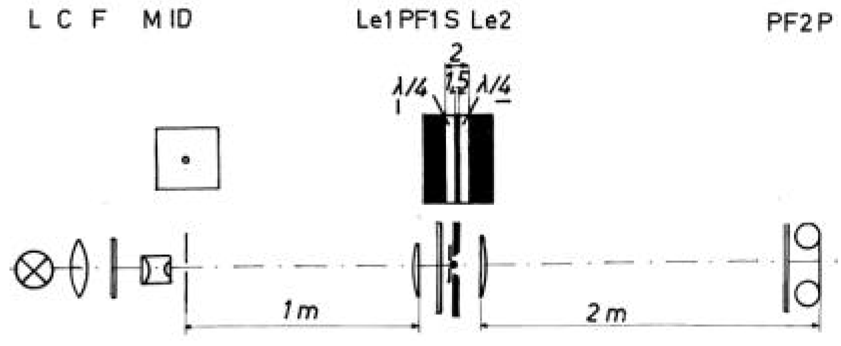


*Figure 3. Experimental arrangement for examination of opposite circular polarized light with the double-slit. L - light-source, a mercury high-pressure lamp HBO 100; C - Condenser; F - green-filter; M -mikroscope-objektive; ID - illumentation circular-opening ~ 0.1 mm; Le 1 - lens f' = 1 m; PF 1 - polarization-filter Zeiss-Bernotar in 45°-position; DS - double-slit with 1.5 mm stick and ever one l /4-plate of glimmer, where the direction of extinction in or 90° to the slits were cut; Le 2 - lens f' = 2 m; PF 2 - polarization-filter, rotating before the camera; P - camera-body of a single-lens reflex-miniature camera.*

Figure 2 shows that the difference of total-intensities parallel and perpendicular to the slit is constant and independent of slit width. Deviations are to find only in very small slit-widths. For an error it is possible that not all light till 180° is recorded by the multiplier. The curves point to a slit-width of

0.003 to 0.004 mm, what is partly depend on the choice of nought-point. Also with a transmitted-light fixed nought-point, smallest 0.002 mm slit-width is necessary for transmit a proportional increasing intensity.

IV. Opposite circular polarized light at the double-slit

Already Fresnel [3] had performed experiments for interference with opposite polarized light with the result that opposite circular polarized light did not interfere. These experiments were repeated with the arrangement figure 3. The incident light was polarized 45° linear. Before every single-slit of the double-slit is placed a part of a quarter-wave plate out of glimmer that was cut out in and opposite extinction direction and originated so opposite circular polarized light. The double-slit had a relative broad middle-stick so that cutting-brim of glimmer, which splinter always, was suffice masked. As to expect, no interference of double-slit is to observe but that of single-slits. Fresnels result was confirmed. If a polarization-filter was brought in, before the film-plane or half near the double-slit, the diffraction-figure of the double-slit originated. By turning the polarization-filter the diffraction-figure moved, at which a turn 180~ caused a moving of a fringe-interval of the double-slit. In equal direction of turning the diffraction-figure moved in the same direction, other direction changed the direction of moving.

If both slits are polarized perpendicular to each other with different cutting polarization-films, so also no interferences of double-slit are to see by turning a behind brought polarization-filter.

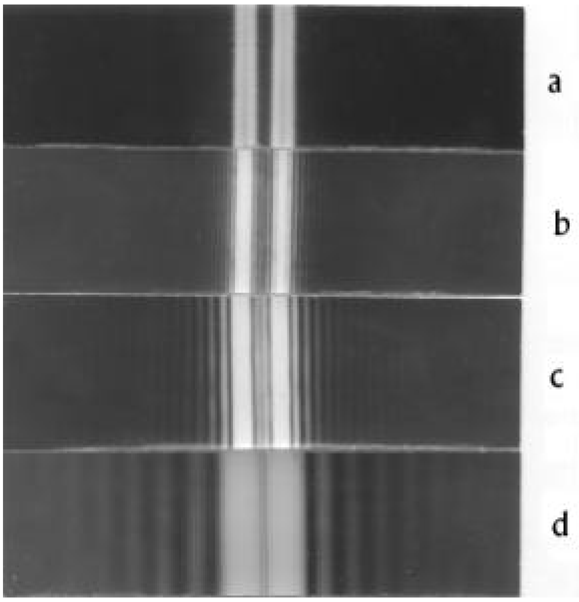


*Figure 4. Diffraction-figures of the double-slit in dependence of the distance to slit. Breadth of middle-stick 1.5 mm, width of single-slits 0.375 mm. Illuminated with parallel mercury light with green-filter. Negatives are tree-fold enlarged.*
*Distance: a: 25 mm, b: 125 mm, c = 275 mm, d = 720 mm..*

V. Building up of diffraction-figure of double-slit

For survey yet is shown the building up of the diffraction-figure of double-slit by parallel incident light with variation of distance. Shortest distances are not respected for Nieke [14] showed how the diffraction-figure of a half-plane is building up, and so originate the inner fringes of slit. At the begin a bright strip appears at the edge, in figure, 4 a this building up is already in progress. Figure 4 b shows the building up of the outer fringes of single-slits that is carried on in figure 4 c. In figure 4 d appear the diffraction-fringes of double-slit

The phenomenon of diffraction-fringes of double-slit is influenced by manner of illumination. Divergent illumination retards the necessary distance, convergent illumination or Fraunhofer's manner of observation shortens the distance.

VI. Discussion of section II and III

Newton [1] book III observation 5 had shown that bent light comes only out of a small surrounding of the edge. Nieke [12], [13] and [14] showed particulars to this fact, light comes out of a surrounding smaller than 0.1 mm of every edge, independent of slit-width. With it is explicable the constant difference independent of slit-width in figure 2: only on bent light exists an influence of direction of polarization, in the middle of the slit passing light is not influenced. Figure 1 show that bent light is not stricken equal but ever the order of bent light the stronger the influence of polarization. Newton [1] III, query 1 supposed that stronger bent light passed near the edge. The stronger influence of polarization can also be connected with it. The change of preference-direction by Bois a. Rubens [10] indicated in optical radiation for an influence of structure of photons and first in Hertz's radiation for a matter-interaction.

VII. Discussion of section IV

According to these results opposite circular polarized light shows only therefore not the diffraction-figure of double-slit because the single components of inter-direction of diffraction-fringes lay side by side and so no diffraction-figure is visible.

Moreover already Fresnel was known that about a plate of glass brought in a light-path of one slit shifts the diffraction-figure of the double-slit.

References

[1] I. Newton, Opticks, or a Treatise of the Reflexions, Refractions, Inflexions and Colors of Light. London 1704;
Opera quae exstant omnis, Tom IV. London 1782;
Optics, Reprint, Bruxells 1966;
Optik II + III, Übers. W. Abendroth, Ostwald's Klassiker Nr. 97, Engelmann Leipzig 1898;
Neuauflage Bd. 96/97 Vieweg, Braunschweig 1983;
Optique, Trac. J. P. Marat, 1787, Bourgois Paris 1989.
[2] J. B. Biot, Traité de physique expérementale at mathématique. Paris 1816, Tome IV.
[3] A. Fresnel, Ann. chim. phys.(2) **28** (1822); Ann. Physik (II) **21** (1831) 276;
Oeuvre complétes I. Paris 1866, S. 731.
[4] V. v. Lang, Sitzungsber. Wien. Akad. **60** (2) (1869) 767; Ann. Physik (II) **140** (1870) 460.
[5] Cornu, Comp. rend. **92** (1881) 1365.
[6] J. J. Thomson, Phil. Mag. (5) **11** (1881) 229; **28** (1889) 1.
[7] W. Wien, Ann. Physik (III) **46** (1886) 117.
[8] H. Hertz, Ann. Physik (III) **36** (1892) 775.
[9] H. du Bois, Ann. Physik (III) **46** (1892) 542.
[10] H. du Bois u. H. Rubens, Ann. Physik (IV) **35** (1911) 243.
[11] G. Wolfsohn, Handbuch der Physik, Bd. XX, S. 305, Springer, Berlin 1928.
[12] H. Nieke, Newtons Beugungsexperimente und ihre Weiterführung. Halle 1997, Comp. Print 1,Arbeit 1.
Newton's Diffraction Experiments and their Continuation. Halle 1997,comp. print 3, paper 1.
[13] As [12], paper 2.
[14] As [12], paper 3.