Interference of light (Item No.: P2220100)

Curricular Relevance

Area of Expertise: ILIAS
Education Level: Physik
Topic: Hochschule
Subtopic: Licht und Optik
Experiment: Ausbreitung von Licht

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	10 Minutes	20 Minutes	2 Students

Additional Requirements:

Experiment Variations:

Keywords:

Wavelength, phase, Fresnel biprism, Fresnel mirror, virtual light source

Introduction

Overview

By dividing up the wave-front of a beam of light at the Fresnel mirror and the Fresnel biprism, interference is produced. The wavelength is determined from the interference patterns.

Fig. 1: Experimental set-up for producing interference with the Fresnel mirror.

Equipment

Position No.	Material	Order No.	Quantity
1	Fresnel biprism	08556-00	1
2	Prism table with holder	08254-00	1
3	Fresnel mirror	08560-00	1
4	Lens, mounted, f = +20 mm	08018-01	1
5	Lens, mounted, f = +300 mm, achrom.	08025-01	1
6	Lens holder	08012-00	2
7	Swinging arm	08256-00	1
8	Slide mount f. opt. pr.-bench, h = 30 mm	08286-01	2
9	Slide mount f. opt. pr.-bench, h = 80 mm	08286-02	2
10	Optical profile-bench, l = 1000 mm	08282-00	1
11	Base f. opt. profile-bench, adjust.	08284-00	2
12	Laser, He-Ne 1.0 mW, 220 V AC	08181-93	1
13	Measuring tape, h = 2 m	09936-00	1

Tasks

Determination of the wavelength of light by interference

1. with Fresnel mirror
2. with Fresnel biprism

Set-up and procedure

The experimental set up for producing interference with the Fresnel mirror is as shown in Fig. 1. The laser (2 cm), the lens holder and lens of focal length *f* = 20 mm (23.3 cm) and a mount with Fresnel mirror (43.2 cm) are mounted on the optical bench. A light surface at a distance of about 2 to 5 m is used as a screen. Before starting the experiment, the movable part of the Fresnel mirror is adjusted so that the two halves of the mirror are approximately parallel. The mirror surface is now aligned parallel to the optical bench. The laser is adjusted that the enlarged beam of rays strikes both halves of the mirror equally. Two light spots, separated by a dark zone, should now be visible on the screen. By turning the adjusting screws of the Fresnel mirror the movable part of the mirror is tilted until these zones overlap. The visible interference pattern and its relationship to the angle of inclination of the mirrors are observed on the screen. The pattern should look like that given in Fig. 4. The experimental set up with the biprism is similar as shown in Fig. 1 (right). The optical bench carries, in addition to the laser and the first lens, a slide mount with a prism table and the biprism (45 cm), and a lens mount with a lens of focal length 300 mm (approx. 60 cm). The widened beam strikes the central edge of the biprism. With the aid of the lens at 60 cm, the two virtual light sources project an image on to a bright surface about 3 m away. The distances between the two points of light, the image-forming lens and the image, and the object distance – lens 1 to lens 2 minus the focal length of lens 1 – are measured. If lens 2 is removed, and interference pattern is observed. The distance between m succesive interference bands is measured.

Caution: Never look directly into a non attenuated laser beam

Theory and evaluation

If light of wavelength λ from two luminous points whose phase difference is constant (coherence) falls on a point *P*, then the two beams of light interfere.

If the two vector amplitudes for propagation in the *x* direction are represented by:

$$s_i = \alpha_i e^{i(Z/\lambda - \delta_i)}$$

where δ_i represents the phases, the individual intensities being given by

$$I_i = s_i \cdot s_i^*$$

the superimposition gives

$$I = I_1 + I_2 + 2\sqrt{I_1 I_2} \cdot \cos\delta$$

where

$$\delta = \delta_1 - \delta_2$$

According to equation (1), *I* possesses maxima and minima as a function of the phase difference δ . In the case of the Fresnel mirror a wave from the light source *Q* falls on to two mirrors inclined at an angle . The interference pattern is observed on the screen *S*. The mirror with light source can be replaced by two coherent light sources Q_1 and Q_2, separated by a distance *d*.

If *r* is the distance between *Q* and the point *A* at which the mirrors are touching, then from Fig. 2:

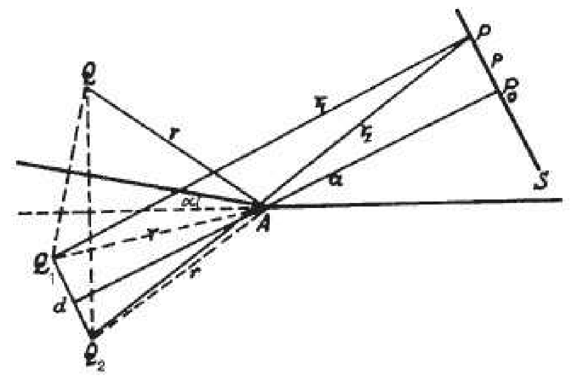

Fig. 2: Geometrical arrangement, using the Fresnel mirror.

$$AQ_1 = AQ_2 = r$$

and

$$d = 2r \cdot \sin\alpha$$

If the distance α between the screen and the mirrors is large compared with the distance between two adjacent interference maxima, the following applies approximately:

$$r_2 = r_1 = \alpha$$

$$r_2 - r_1 = \frac{pd}{\alpha}$$

since

$$(r_2 - r_1)(r_2 + r_1) = 2pd$$

The phase difference δ is thus

$$\delta = 2\pi \frac{r_2 - r_1}{\lambda} = \frac{2\pi pd}{\lambda\alpha}$$

According to equation (1), maxima occur on the screen for distances p equal to:

$$p = n\frac{\lambda\alpha}{d}, n = 0, 1, 2, 3, \ldots \qquad (2)$$

and minima for

$$p = (n + \frac{1}{2}\frac{\lambda\alpha}{d}, n = 0, 1, 2, \ldots \qquad (3)$$

$$\frac{1}{g} + \frac{1}{b} = \frac{1}{f}$$

$$\frac{g}{b} = \frac{d}{B}$$

where *g* and *b* represent the object-to-lens and the image-tolens distance respectively.

$$d = \frac{B \cdot f}{b - f} \qquad (4)$$

(See experiment 2.1.2-00 “Law of lenses and optical instruments”)

$$\delta = 2\pi\frac{r_2 - r_1}{\lambda} = \frac{2\pi pd}{\lambda\alpha}$$

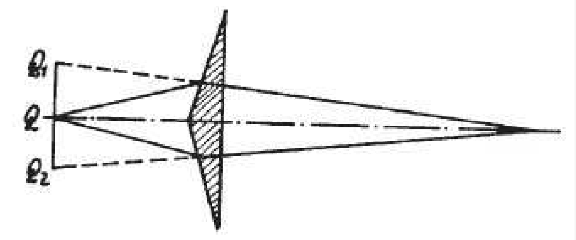

Fig. 3: Geometrical set up, using the Fresnel biprism.

From this, and from equation (2) or (3), λ was determined as the mean of various measurements, using different angles of inclination of the mirror.

n = 1 and formula (2)

$$p = \frac{\lambda\alpha}{d}$$

or

$$\lambda = \frac{dp}{\alpha}$$

with

$$d = \frac{B \cdot f}{b - f}$$

d is the distance between two neighbouring maxima.

λ = 626.5 nm.

In the case of the Fresnel biprism the distance d is determined exactly as for Fresnel mirror, using equation (4).

Equation (3), similarly, applies for the distance p between the interference bands if the effect of the refractive index and the thickness of the prism are neglected. Using equations (4), (3) and (2), the value for λ was determined as

λ = 624.0 nm.

Literature value: 632.8 nm

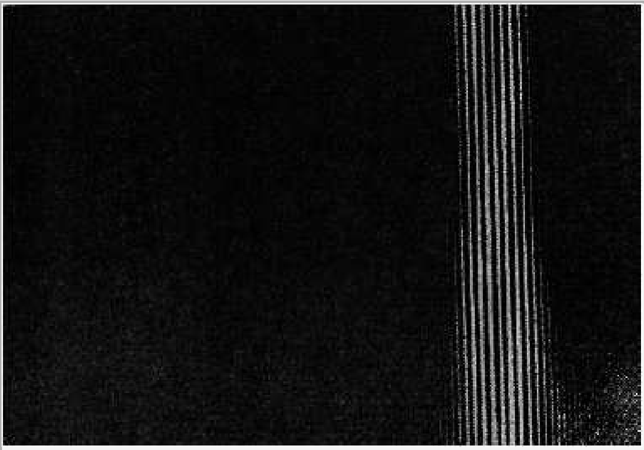

Fig. 4: Interference pattern of the Fresnel mirror.