Interference experiment

Physics | Light & Optics | Dispersion of light

Difficulty level	Group size	Preparation time	Execution time
-	-	-	-

This content can also be found online at:

http://localhost:1337/c/5f0ebc85a66f81000378bc18

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General information

Application

An example of hologram image

The principles of interference can be found in holography which was first introduced in 1948 by Denies Gabor. In general, two beams, which are reference beam and object beam are intersect and interfere with each other to form an interference pattern. Hologram is stored in a recording medium and can be reconstructed into three-dimensional images.

An electron version of the Fresnel biprism is used in electron holography, an imaging technique that photographically records the electron interference pattern of an object. The hologram is then illuminated by a laser resulting in a greatly magnified image of the original object. This technique was developed to enable greater resolution in electron microscopy than is possible using conventional imaging techniques.

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Other information (1/2)

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Prior knowledge

Interference is a phenomenon, in which two light waves superpose to form a resultant wave of greater, lower or same amplitude. In order to observe the interference in light, the sources must be coherent and emit the same wavelength.

Scientific principle

1. In constructive interference, the resultant amplitude at a given position or time is greater than that of either individual wave
2. In destructive interference, the resultant amplitude is less than that of either individual wave

Other information (2/2)

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Learning objective

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.

Tasks

Determination of the wavelength of light by interference

1. with Fresnel mirror,
2. with Fresnel biprism.

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Safety instructions

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- The common rules of safe experimentation in scientific education apply in this experiment.
- The generally applicable rules for handling lasers according to the ANSI and IEC Laser Classification must be considered.
- Do not see directly into the laser beam and reflected beam
- Use suitable screening to isolate the area around the laser and avoid unwanted reflections.

Theory (1/5)

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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:

$$s_i = a_i e^{i(z/\lambda - \delta_i)}$$

where δ_i represents the phases, the individual intensities being given by $I_i = s_i . s_i^*$, the superimposition gives

$$I = I_i + I_2 + 2\sqrt{I_1 I_2}\cos\delta \qquad (1)$$

where $\delta = \delta_1 - \delta_2$

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Theory (2/5)

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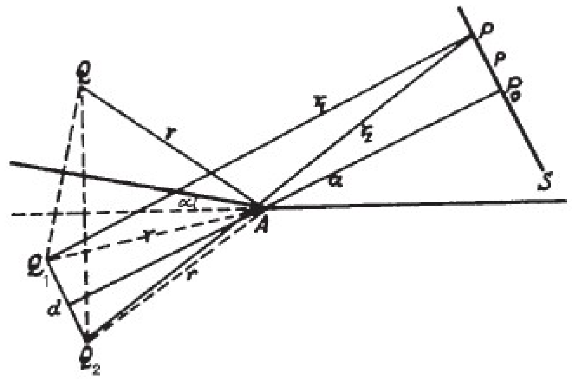
According to equation (1), I possesses maxima and minima as a function of the phase difference δ. In the case of the Fresnel mirror a wave from the light source Q falls on to two mirrors inclined at an angle α. The interference pattern is observed on the screen S. The mirror with light source can be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

$$AQ_1 = AQ_2 = r \quad \text{and}$$

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



Geometrical arrangement, using the Fresnel mirror.

Theory (3/5)

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

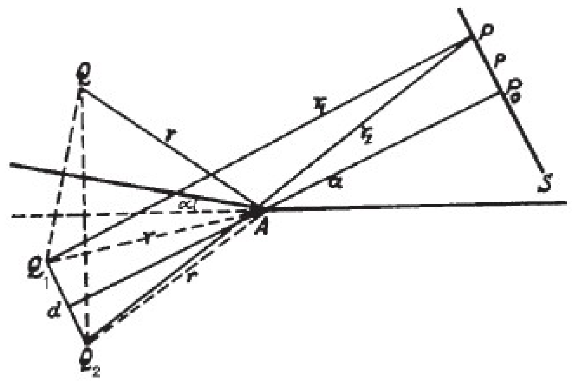
$$r_2 = r_1 = a \quad \text{and} \quad r_2 - r_1 = \frac{pd}{a}$$

since

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

The phase difference δ is thus

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



Geometrical arrangement, using the Fresnel mirror.

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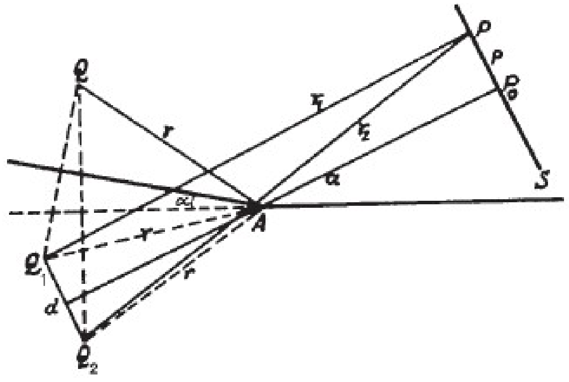
Theory (4/5)

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

$$p = n\frac{\lambda a}{d}\ ,\quad n = 0, 1, 2... \qquad (2)$$

and minima for

$$p = (n + \tfrac{1}{2})\frac{\lambda a}{d}\ ,\quad n = 0, 1, 2... \qquad (3)$$



Geometrical arrangement, using the Fresnel mirror.

Theory (5/5)

The distance *d* between the two virtual light sources is determined by projecting a sharp image of them on the screen, using a lens of focal length *f* and measuring the size of the image *B*:

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

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

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

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

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Equipment

Position	Material	Item No.	Quantity
1	Fresnel biprism	08556-00	1
2	Prism table with holder	08254-01	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	Slide mount for optical bench expert, h = 30 mm	08286-01	3
8	Optical bench expert, l = 1000 mm	08282-00	1
9	Base for optical bench expert, adjustable	08284-00	2
10	Diodelaser, green, 1 mW, 532 nm	08765-99	1
11	Measuring tape, l = 2 m	09936-00	1
12	Digital array camera	35612-99	1
13	Barrel base expert	02004-00	1
14	Slide mount for optical bench expert, h = 80 mm	08286-02	1
15	Stand tube	02060-00	1

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Setup and procedure

Setup (1/2)

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

Experiment with Fresnel mirror

- 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.
- The movable part of the Fresnel mirror is adjusted so that the two halves of the mirror are approximately parallel. The mirror surface is aligned parallel to the optical bench.

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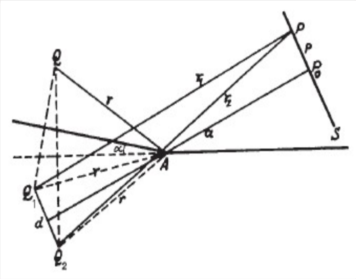
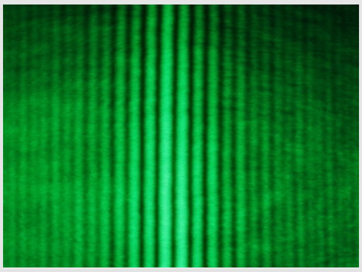
Setup (2/2)

Experiment with Fresnel biprism

- The experimental set up with the biprism is similar as with Fresnel mirror.
- 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).

Procedure (1/2)





Experiment with Fresnel mirror

- 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 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.

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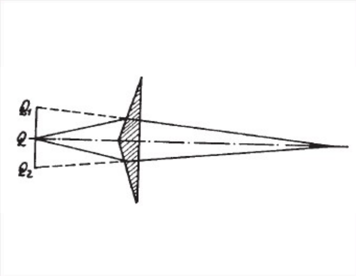
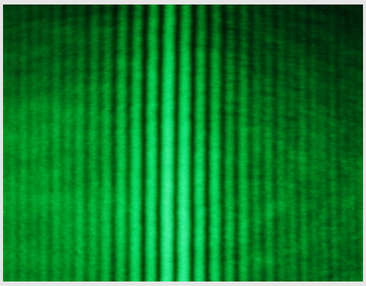
Procedure (2/2)

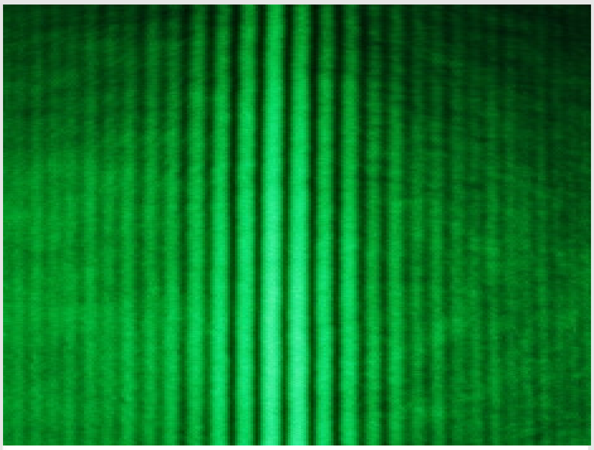




Experiment with Fresnel biprism

- 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.

Evaluation (1/3)



Interference pattern of the Fresnel mirror

Using equation (2) or (3), λ is determined as the mean of various measurements using different angles of inclination of the mirror. When $n = 1$,

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

with

$$d = \frac{Bf}{b-f}$$

d is the distance between two neighbouring maxima. The effect of the refractive index and the thickness of the prism are neglected.

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Evaluation (2/3)

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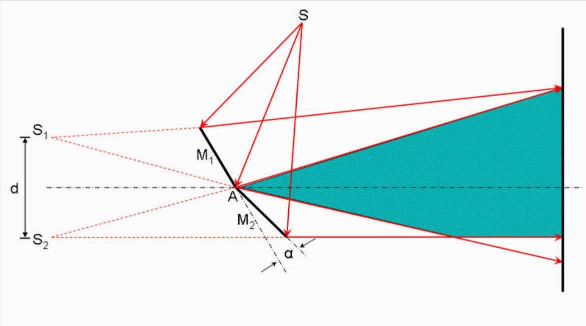
What happens to the distance between the first maximum and the central maximum as the two slits are moved closer together?

- The distance decreases
- The distance increases
- The distance remain the same

Check



The interference of Fresnel mirror

Evaluation (3/3)

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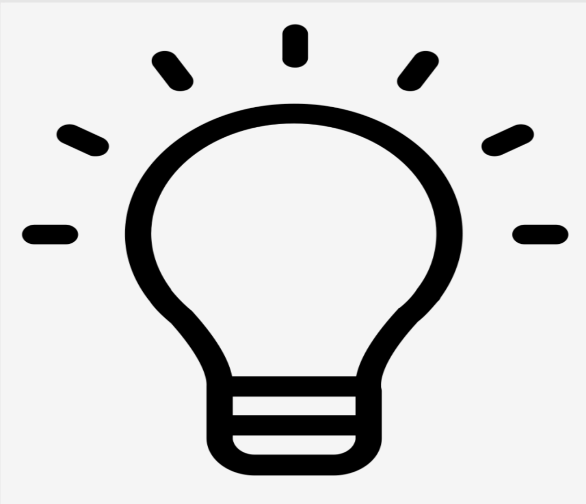
If instead of monochromatic light white light is used for interference of light, what would be the change in the observation?

- The bright and dark fringes will change position
- Colored fringes will be observed with a white bright fringe at the center
- The pattern will not be visible

Check



A white light bulb

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Slide	Score / Total
Slide 18: Interference	0/1
Slide 19: White light	0/1

Total Score 0 / 2

Show solutions Retry

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