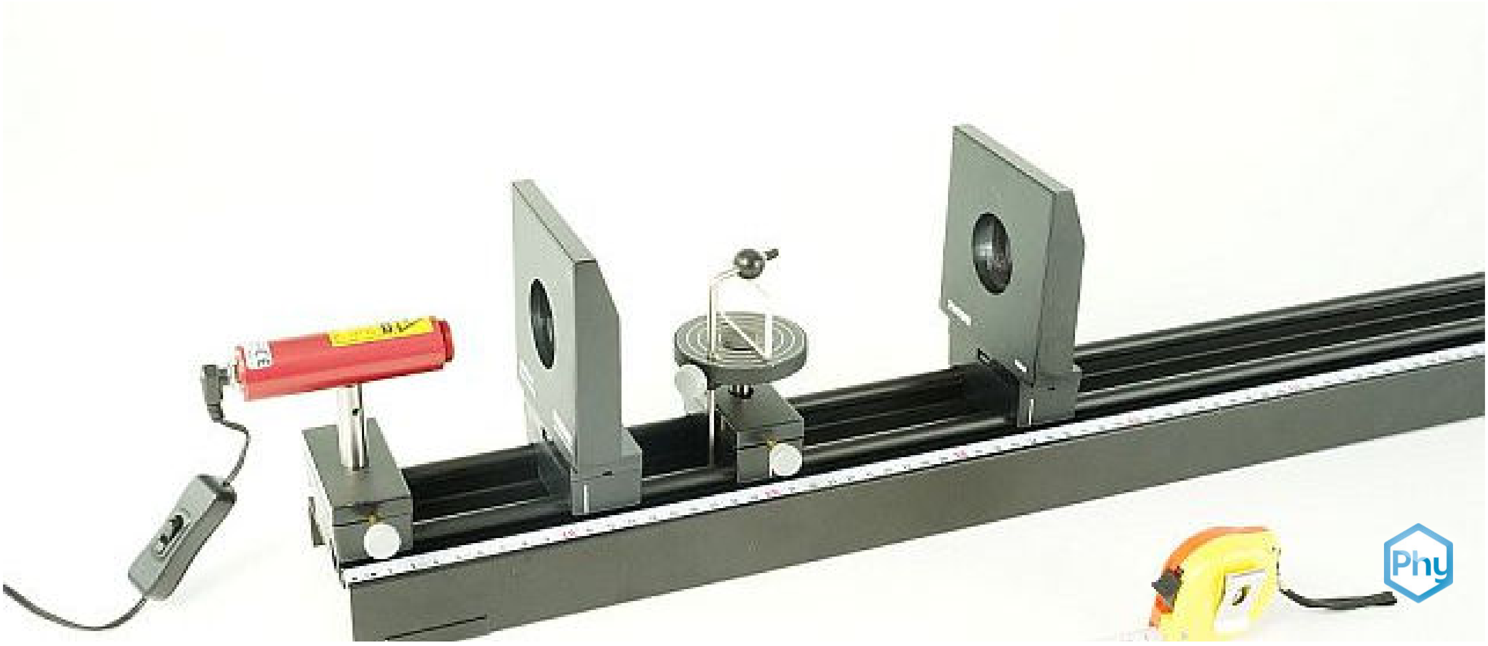
Generation of interferences with a Fresnel biprism



With the help of a prism with a very large apex angle (Fresnel biprism), an incident light beam can be split into two equal coherent partial beams that interfere with each other in their overlap area

Physics › Light & Optics › Diffraction & interference

Difficulty level	Group size	Preparation time	Execution time
medium	-	10 minutes	20 minutes

This content can also be found online at:

http://localhost:1337/c/639acf7ef1828f0003e7992a

General information

Application

Experimental setup

With the help of a prism with a very large vertex angle (Fresnel biprism), an incident light beam can be split into two equal coherent partial beams that interfere with each other in their overlapping area.

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Other teacher information (1/2)

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Prior knowledge

To understand this experiment, students should already be familiar with the wave behaviour of light. For illustration purposes, it can be helpful to show interference of water waves beforehand.

Principle

The light waves from the laser fall on the lens, are expanded and hit the biprism. This makes it possible to create two virtual light sources from the real light source.

Interference occurs in the overlapping area of the two light sources, which can be seen on the screen.

Other teacher information (2/2)

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Learning objective

If a laser beam expanded with the help of a converging lens falls centrally on a biprism, bright and dark stripes are created behind it due to interference of the partial beams.

If the distance between the two virtual light sources is known, the wavelength of the laser light can be determined from the distance between two neighbouring bright or dark stripes.

Tasks

- Generation of interference with the help of a Fresnel biprism.
- Determination of the wavelength of the diode laser.

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Safety instructions

It is essential to avoid looking directly into the laser light.

The general instructions for safe experimentation in science lessons apply to this experiment.

Theory (1/3)

A parallel beam of light emanating from a laser is collected with the aid of a short focal length converging lens. L_1 flared out and meets the vertex of a biprism in the middle P. The partial beams created in this way can be directed onto two virtual light sources as shown in Fig. 1. Q_1 and Q_2 can be traced back.

In the overlapping area of the two coherent partial beams, they can interfere with each other. On a screen S an interference pattern of light and dark parallel stripes can be observed. If the distance d of the two virtual light sources Q_1 and Q_2 known, then from the distance x_k of two adjacent light or dark stripes the wavelength λ of the laser light can be determined.

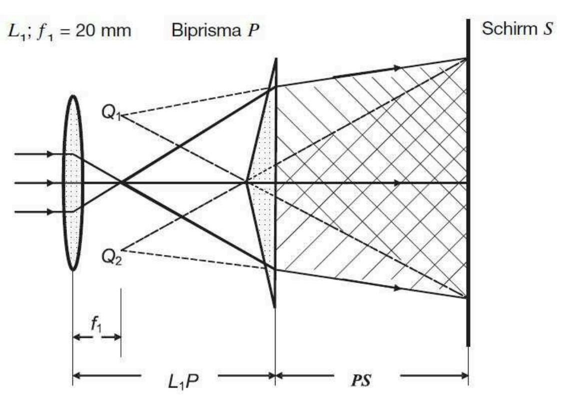


Fig. 1

Theory (2/3)

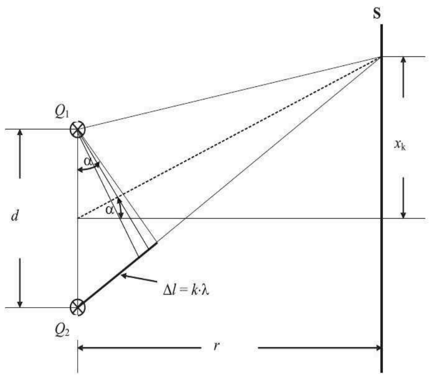


Fig. 2

Brightness maxima are always to be expected when the passage difference Δl of two partial beams is an integer multiple of k the wavelength λ amounts.

According to Fig. 2:

$$\sin\alpha = \frac{\Delta l}{d} = \frac{k*\lambda}{d} = \frac{x_k}{\sqrt{x_k^2+r^2}}; (k = 0, \pm1, \pm2, \dots) \ (1)$$

From (1) it follows for the wavelength λ:

$$\lambda = \frac{x_k}{k} * \frac{d}{\sqrt{x_k^2+r^2}} \qquad (2)$$

Theory (3/3)

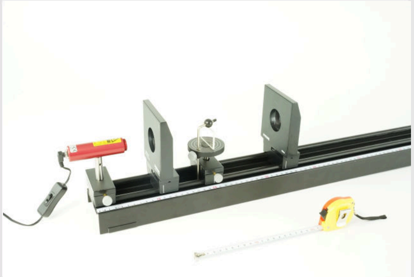
To determine the distance d of the two virtual sources Q_1 and Q_2 these are collected with the aid of a second collecting lens L_2 is shown on the screen magnified by the distance. According to the imaging law for lenses, the following applies:

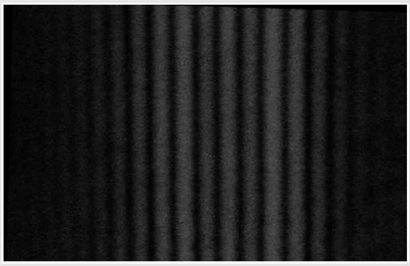
$$\frac{g}{d} = \frac{d}{d^*} \rightarrow d = \frac{d^* * g}{b} \qquad (3)$$

(g = subject width, b = Image width, d = distance from Q_1 and Q_2, d^* = image distance from Q_1 und Q_2)

With (3) and (2) one finally obtains for the wavelength:

$$\lambda = \frac{x_k}{k} * \frac{d^* * g}{b} * \frac{1}{\sqrt{x_k^2+r^2}} \qquad (4)$$





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Equipment

Position	Material	Item No.	Quantity
1	Optical profile-bench, l = 1000 mm	08370-00	1
2	Diodelaser, red, 1 mW, 635 nm	08761-99	1
3	Fixing unit for diode laser	08384-00	1
4	Slide mount for optical bench	09822-00	2
5	Fresnel biprism	08556-00	1
6	Mount with scale on slide mount	09823-00	2
7	Prism table with holder for optical base plate	08725-00	1
8	Lens, mounted, f +20 mm	08018-01	1
9	Lens, mounted, f +300 mm	08023-01	1
10	Screen, white, 150x150 mm	09826-00	1
11	Barrel base expert	02004-00	1
12	Vernier calliper stainless steel 0-160 mm, 1/20	03010-00	1
13	Measuring tape, l = 2 m	09936-00	1

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Additional material

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Position	Equipment	Quantity
1	adhesive tape	1
2	white sheet of paper	1

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Structure and implementation

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Set-up

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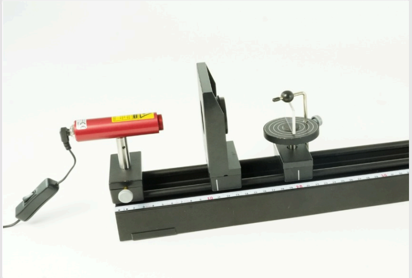
The experimental set-up is as shown in Fig. The tally marks of the components on the optical bench have the following positions:

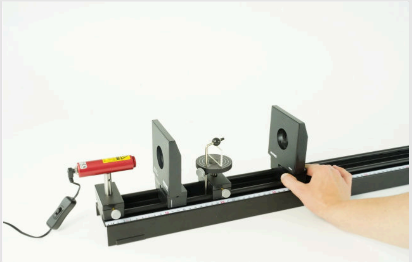
- Slide mount with diode laser at $1,5cm$
- Mount with scale with lens L_1 with $f_1 = 20mm$ bei $11,0cm$
- Slide mount with prism table and biprism at $20,0cm$

To determine the image distance of the virtual light sources is added later:

- Mount with scale with lens L_2 with $f_2 = 200mm$ at $34,0cm$

At a distance of approx. $3m$ from the end of the optical bench, the screen is in a barrel base.





Procedure (1/2)

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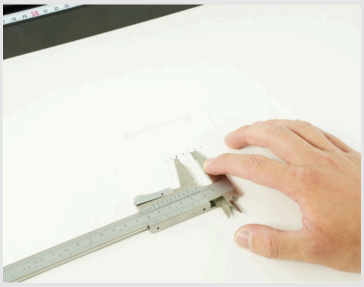

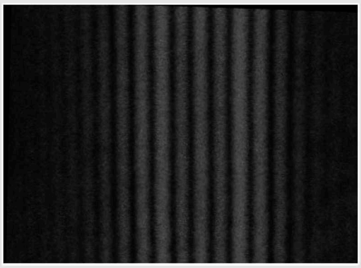

To expand the laser beam, the converging lens with focal length $f_1 = +20mm$ into the mount at $11cm$ inserted. The biprism is fixed on the prism table in such a way that its vertex coincides with the optical axis and points in the direction of the laser. The expanded laser beam must hit the vertex of the prism symmetrically.

On the screen, to which a white sheet of paper has previously been attached with stripes of adhesive tap, the interference pattern of vertically running light and dark parallel stripes is now to be observed. With the help of a water-soluble felt-tip pen, the centres of the light stripes are marked at the same height and their distances are determined with the help of calipers after removing the paper. To determine the distance between two maxima as accurately as possible, it is useful to measure several lines symmetrically to the centre of the interference pattern.

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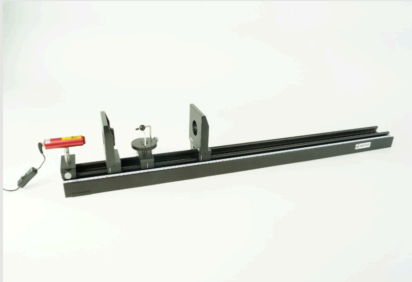
Procedure (2/2)

Subsequently, in addition to the enlarged image of the distance between the two virtual light sources, the lens is l_2 with $f_2 = +200mm$ into the mount at $34cm$ used.

Move the slide mount on the optical bench slightly until two sharp points of light - the images of the virtual light sources - can be seen on the screen, whose distance from the optical bench must not be changed. As before, mark the positions of the light points on a sheet of paper on the screen and determine their distance again with the caliper.

The tape measure is used to measure both the image width b (distance screen-lens L_2) as well as the object width g (distance between the two lenses L_1 and L_2 minus the focal length f_1) determined.



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Evaluation

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Evaluation (1/3)

The evaluation of the experiment provides the following values:

$x_k = 37mm$

$k = 15$

$b = 3240mm$

$g = L_1L_2 - f_1 = 210mm$

$r = g + b = 3450mm$

$d^* = 14mm$

Drag the words into the correct boxes!

g =

b =

d =

d^* =

image distance | object distance

distance Q_1 and Q_2

image distance Q_1 and Q_2

Check

Evaluation (2/3)

With these measured values, the result is for the wavelength of the diode laser:

$$\lambda = 2,47 * \frac{14*210}{3240} * \frac{1}{\sqrt{37^2+3450^2}} mm = 649,6 * 10^{-6} mm \approx 650nm$$

A comparison with the wavelength specified in the data sheet of the diode laser of $\lambda = 635nm$ shows that the value determined by the experiment is lower by approx. $2,4\%$ is too large. The main sources of error lie in the determination of d^* and the quotient x_k/k. The accuracy of the latter can be increased if the distances of different lines are measured symmetrically to the central maximum in the interference image and the mean value of the quotient is determined from this.

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Evaluation (3/3)

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Brightness maxima are always to be expected when the path difference Δl of two partial beams is an integer multiple of k the wavelength λ amounts.

- True
- False

Check

The distance between the two virtual light sources Q_1 and Q_2 is not necessary for the determination of the wavelength λ of the laser light.

- True
- False

Check

Slide	Score / Total
Slide 16: Assign terms	**0/4**
Slide 18: Multiple tasks	**0/2**

Total **0 / 6**

Solutions Repeat

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