

Interference at a Fresnel's mirror with an He-Ne laser

Objects of the experiment

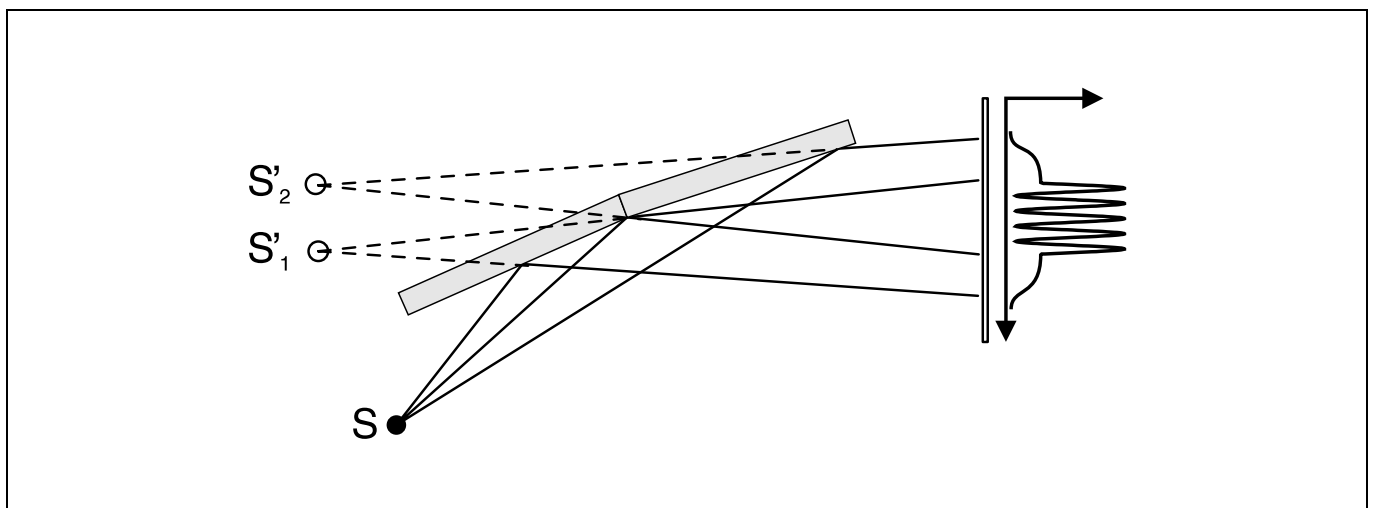
- To generate two virtual, coherent light sources through reflection of a point-shaped light source at a Fresnel's mirror.
- To observe the interference of the two virtual light sources.
- To measure the distance d of the interference lines.
- To generate projected images of the virtual light sources.
- To measure the distance A of the projected images.
- To determine the wavelength λ of the light of an He-Ne laser from the distance d of the interference lines, the distance A of the projected images of the virtual light sources and the geometrical dimensions of the assembly.

Principles

The Fresnel's mirror consists of two plane mirrors, slightly angled with respect to each other. A point light source S reflected in a Fresnel's mirror appears as a pair of virtual light sources S_1' and S_2' positioned close together, which interfere with each other due to their coherence. This gets around the problem that two separate light sources do not produce observable interference phenomena on account of their incoherence. Two virtual coherent light sources are produced by reflection of a single light source. The light reflected by the Fresnel's mirror is permeated by a system of parallel interference lines.

In this experiment, the light source S is the same as the focal point of the lens used to broaden the laser beam. To determine the wavelength λ of the He-Ne laser light used in this experiment, we must first find the distance d between two intensity

maxima. Then, the two virtual light sources S_1' and S_2' are imaged on the observation screen using a second lens, and the distance A of the projected images is measured. As the geometrical dimensions of the setup are known, we can use these data to determine the distance a between the virtual light sources.



Apparatus

1 He-Ne laser, linearly polarized	471 840
or	
1 He-Ne laser, 0.2/1 mW	471 83
1 Fresnel's mirror, adjustable	471 05
1 Lens, f = 5 mm	460 01
1 Lens, f = 200 mm	460 04
1 Optical bench, 1 m, standard cross-section	460 32
3 Optics riders, height: 60 mm/width: 36 mm	460 353
1 Optics rider, height: 60 mm/width: 50 mm	460 351
1 Translucent screen	441 53
1 Saddle base	300 11
1 Vernier calipers, plastic	311 52
1 Steel tape measure	311 77

For a large distance L between the light source and the observation screen, we can calculate the wavelength λ of the light used from the quantities a and d as follows:

Two coherent waves are observed which originate at S_1' and S_2' and propagate in the direction ϑ (see Fig. 1, top). ϑ is the direction of the n th intensity maximum, when for the path difference

$$\Delta s = a \cdot \sin \vartheta$$

of the two waves the following applies:

$$\Delta s = n \cdot \lambda.$$

For the distance D_n between the 0th and the n th maximum, the geometrical relationship

$$\tan \vartheta = \frac{D_n}{L}$$

applies. For large distances L , $\sin \vartheta \approx \vartheta$, and we obtain

$$\lambda = a \cdot \frac{D_n}{n \cdot L} = a \cdot \frac{d}{L} \tag{I}.$$

The distance a between the virtual light sources is determined using their distance A in the projected image. From the geometry of the experiment, we obtain the relationship:

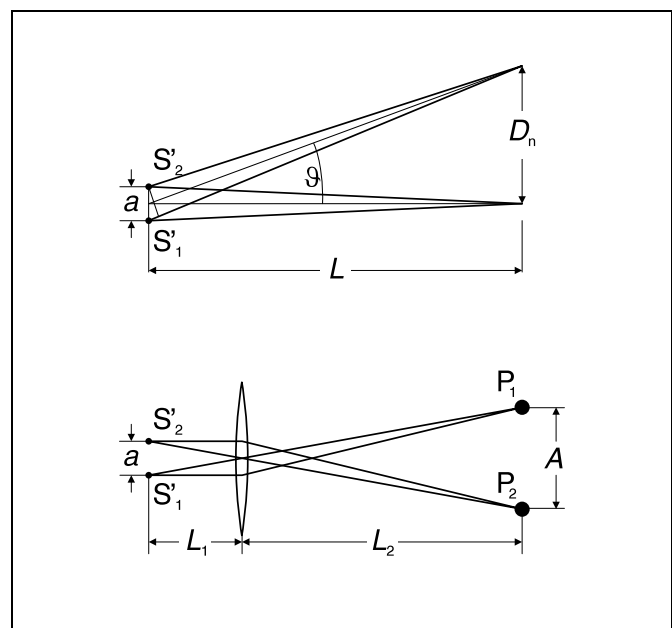
$$a = A \cdot \frac{L_1}{L_2} \tag{II}$$

Fig. 1: Top: beam path without 200 mm lens for two-beam interference.
Bottom: beam path for projection of the virtual light sources on the projection screen using a 200 mm lens

Safety note

The He-Ne laser fulfills the German technical standard "Safety Requirements for Teaching and Training Equipment – Laser, DIN 58126, Part 6" for class 2 lasers. When the precautions described in the Instruction Sheet are observed, experimenting with the He-Ne laser is not dangerous.

- Never look directly into the direct or reflected laser beam.
- Do not exceed the glare limit (i.e. no observer should feel dazzled).



Setup

Note:

Diffraction of the laser light at the outside edge of the Fresnel's mirror can cause unwanted diffraction patterns on the observation screen, which can easily be confused with the desired interference pattern. One way to recognize them is that their position does not depend on the angle of the mirror sections to each other.

Before each measurement, change the angle of the mirror sections to each other using the knurled screw (3) and check whether the distance between the interference lines changes.

Fig. 2 shows the experiment setup. The positions of the left edge of the optics riders are given in cm.

- Attach the optics riders at the given positions on the optical bench and set up the translucent screen on the saddle base at least 2 m from the optical axis.
- Adjust the laser and the 5 mm lens (1) on the optics riders so that the center of the broadened laser beam runs parallel to the optical bench. You may need to trace the beam path with a piece of paper.
- Set up the 200 mm lens (2) so that the translucent screen is illuminated.
- When mounting the Fresnel's mirror, make sure that the broadened laser beam falls on the separating edges of the two half-mirrors. Incline the mirror only very slightly, so that the laser beam just grazes the mirror and the reflected light travels virtually in parallel to the optical bench. Use the vertical adjustment with respect to the optical axis via knurled screw (4) and make sure that the reflected light falls on the center of lens (2).
- Adjust lens (2) until both virtual light sources are sharply imaged on the translucent screen (move the rider on the optical bench if necessary).

Laser light which bypasses the Fresnel's mirror produces a third light spot on the screen to the left of the two projected images. This does not affect the experiment in any way.

- Using knurled screw (3), set the distance A between the two projected images to about 5 mm when the screen is positioned approx. 2 m away.

Carrying out the experiment

a) Interference of the two virtual light sources:

- Remove lens (2) from the optics rider.
- Use knurled screw (3) to adjust a high-contrast interference pattern. You may need to hold a piece of white paper in front of the screen.

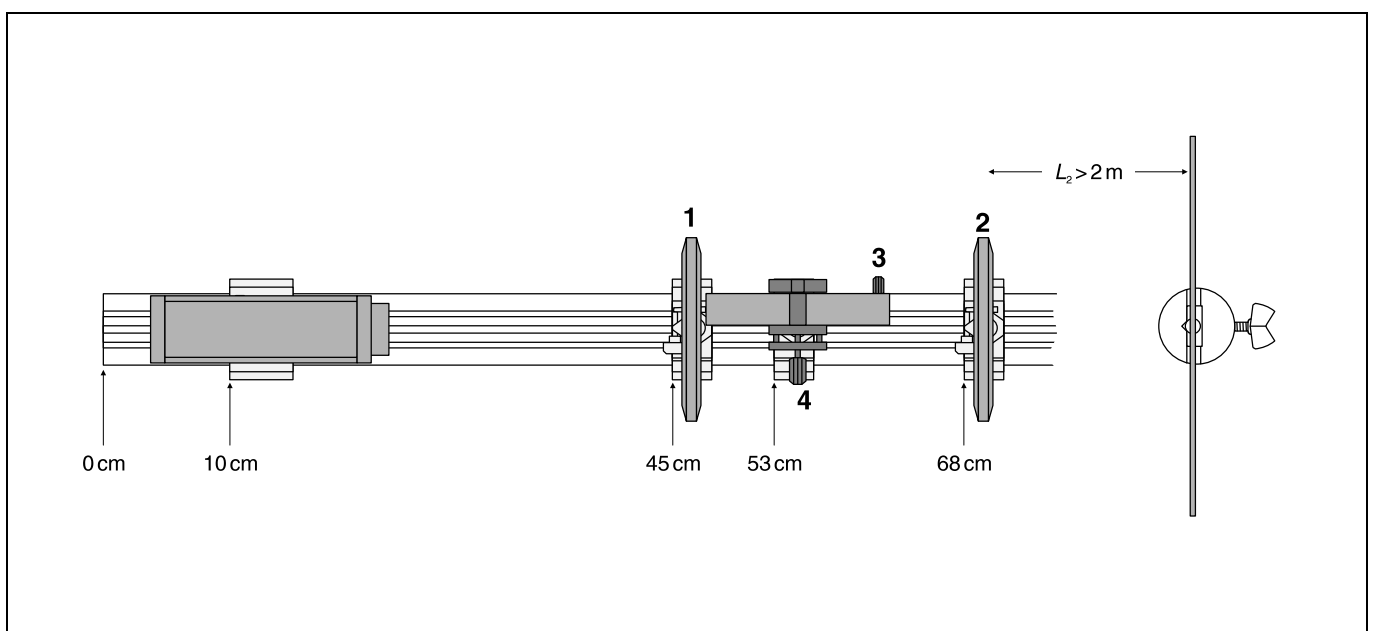
If the diffraction at the outer front edge of the Fresnel's mirror causes an additional, distracting interference pattern:

- Using knurled screw (4), change the position of the Fresnel's mirror until the divergent laser beam is no longer incident on the outer edge.
- Using the vernier calipers, measure the distance d between lines and write this value down.

b) Projecting the virtual light sources:

- Insert lens (2) and readjust it as necessary to obtain a sharply focused image of the virtual light sources. Measure the distance d between lines with the vernier calipers and write this value down.
- Read the distance L_0 between lens (2) and lens (1) from the scale of the optical bench and write this value down.
- Using the steel tape measure, measure the distance L_2 between the projected image and lens (2), and write down this value.
- If desired, remove the lens, create a new interference pattern and repeat your measurements.

Fig. 2: Experiment setup on the optical bench, with position specifications for the left edge of the optics rider



Measuring example

$$d = 3.9 \text{ mm}$$

$$A = 4.3 \text{ mm}$$

$$L_0 = 22.7 \text{ cm}$$

$$L_2 = 230.5 \text{ cm}$$

Evaluation

The point-shaped light source is located in the focal point of the 5-mm lens; thus, $L_1 = L_0 - 5 \text{ mm}$. For the distance L between the light sources and the projection screen, we can say that $L = L_1 + L_2$. Using equations (I) and (II), we can calculate first $a = 0.41 \text{ mm}$, and then, using this value, the wavelength of the laser light used ($\lambda = 640 \text{ nm}$); this agrees quite well with the literature value $\lambda_{\text{HeNe}} = 632.8 \text{ nm}$.

Results

The interference pattern generated using a Fresnel's mirror can be explained through the interference of two light beams.

Through reflection of a point-shaped light source in a Fresnel's mirror, two virtual light sources are created, which are coherent and thus interfere with each other.