Apparatus Competition
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Simple Lloyd's Mirror

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Abstract

Lloyd's Mirror is used to produce two-source interference patterns, similar to the pattern produced by laser light passing through two slits. A diverging laser beam strikes a front-surface mirror at a low angle, so that some of the beam reflects off the mirror to a screen, and some shines directly on the screen. The reflected beam forms a virtual second source that interferes with the direct beam. Varying that separation between the laser and the mirror changes the interference pattern on the screen.

Construction of Apparatus:

This version of Lloyd's mirror is much simpler than many previous versions, is bright enough to be shown to a large class, and is easy to set up. It consists only of a 30 mW green laser module with power supply, a converging lens of short focal length, and a small front-surface mirror.

Because the laser is fairly high-powered (for improved visibility), it has been mounted in a homemade heat sink (aluminum block) to prevent overheating in operation. The converging lens in front of the laser causes the beam to first converge, then diverge in a wide cone. Because the laser beam has been spread out many times its original size, the light is rendered safe for viewing and no extensive safety precautions are needed.

To simplify adjustment of the laser-to-mirror separation, the laser has been mounted on a small plastic jeweler's vise. Opening and closing the vise changes the distance from the laser to the mirror's reflective surface in a smooth fashion, but the vise is only for convenience and it is not difficult to achieve the effect simply by mounting the laser/lens and the mirror on separate ring stands and sliding one past the other on a table.

A white viewing screen is the only other requirement, but a meter stick or other measuring tool placed against the screen may be used to measure the fringe separation as a function of distance from the mirror.

Use of Apparatus:

Lloyd's mirror is an interesting example of two-source interference, which is similar to but subtly different from two-slit interference.

To operate the apparatus, begin with the vise opened wide, so that the laser is as far from the mirror as possible. Turn the laser on, then turn the screw on the vise to move the laser in toward the mirror. At first you will see simply a bright circle of light from the diverging beam directly striking the screen, and a second partial circle from a partial reflection off the mirror. As the laser is brought closer to the mirror, these two spots become more equal in size and increasingly overlap.

When the path-length difference is small enough, closely-spaced vertical fringes will become apparent in the light on the screen. As the laser moves closer to the mirror, the spacing of the fringes increases and the number of visible fringes decreases until they finally disappear. At that point the laser has passed the reflecting front surface of the mirror.

Because the two sources do not pass through narrow slits, there is no diffraction pattern for the individual sources. Because the sources do not cause their own diffraction patterns, Lloyd's mirror is an example of two-source interference without the confusion of an overlaid diffraction pattern.

It is also interesting because the light reflecting off the mirror undergoes a 180º phase shift upon reflection, causing the fringe pattern to invert – when compared to a two-slit pattern from slits of the same separation, there are bright fringes in one pattern where there are dark fringes in the other, and vice-versa. Humphry Lloyd noted this discrepancy shortly after he discovered the effect in 1834, and interpreted it as a definitive proof that the phase of the reflected beam was being inverted.

Thus whereas the n^{th} bright fringe for two slit interference can be shown to obey the relationship:

$$x_n = n\lambda(D/d)$$

The n^{th} bright fringe for Lloyd's Mirror obeys the relationship:

$$x_n = (n - \tfrac{1}{2})\lambda(D/d)$$

Where:

x_n = the distance from the center of the pattern to the n^{th} bright fringe,
λ = the wavelength of the light (532 nm in this case),
D = distance to the screen, and
d = separation between the two sources (slits in one case, source and reflected "source" in the other)

The separation *between* bright fringes (x) is thus found by subtracting x_n from x_{n+1} For both cases:

$$x = \lambda(D/d)$$

Thus if x, D, and d are known it is a simple matter to determine λ for the laser beam.

In a dark room, the apparatus can be moved back to 3-5 meters from the screen, enlarging the pattern so that it is easily visible for demonstrations.