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LASER APPLICATIONS

INTRODUCTION

Lasers and diffraction techniques are widely used in research laboratories and industry. Their operating principle is described briefly in the optics tutorial which was introduced in Experiment 9, under topic 5 of the main menu. Follow the previous instructions (or ask your instructor if you need help) to look up this brief animated introduction to lasers. A particularly useful property of laser beams is the small amount of spreading even after very large distances. We will measure the rate of spreading of a typical laser beam in today's laboratory activity. Another important property of a laser beam is the well defined wavelength value of the laser light. We will make use of this property to measure very small diameters by a diffraction technique as an illustration of an application.

DIVERGENCE OF A LASER BEAM

Because a laser beam consists of very nearly parallel light rays, the beam diameter increases far more slowly with distance from the light source than e.g. the light beam from a flashlight. This makes laser beams very useful for alignment applications in large construction projects, surveying, monitoring seismic activity, etc. By reflecting a laser beam off a mirror placed on the moon, it is even possible to monitor lunar seismic activity!

In order to determine the divergence, or spreading rate, of a laser, we will measure the beam diameter as a function of distance from the laser. The best place for this experiment is probably in the hallway outside the laboratory. Using graph paper or a ruler with 1 mm spacing between lines, measure the beam diameter at a number of distances from the laser at intervals of several meters. You will note that the edge of the beam is somewhat fuzzy, and you will need to determine some criterion for the "beam size." Plot beam diameter vs. distance and calculate the angular beam divergence from the slope of a line drawn through your data. The change in diameter divided by the corresponding increase in distance from the laser is the tangent of the spreading angle. If the angle q is measured in radians (2p radians = 360°), it is very nearly true for small angles that tan q = q. Therefore the slope of your curve equals the beam divergence, conventionally expressed in units of milliradians.

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The mean earth-moon distance is $3.84 \cdot 10^5$ km. If your laser beam was pointed toward the moon, how large a diameter would the beam have when it reached the moon's surface? (Compare this with the moon's diameter, which is $3.4 \cdot 10^3$ km.

The cross sectional area of your laser beam is proportional to the square of the diameter, and the brightness of the beam is proportional to the constant power emitted by the laser divided by the cross sectional area. Use this information and the results of your measurements to determine how far the laser beam must travel before its brightness is reduced by a factor of 100 from its value at a shorter distance.

DIAMETER OF A HUMAN HAIR

We have previously examined the diffraction pattern which results when light of a given wavelength passes through a narrow slit. It can be shown that the same diffraction pattern results when a light beam is blocked by a narrow obstruction of the same width as the slit. This is perhaps an astonishing result, but can be used e.g. to measure fairly accurately the diameters of extremely fine wires.

Let a screen be located at a distance D from a slit or from a narrow obstruction of width a. For light of wavelength l, we learned that intensity minima occur when $y = n\, \mathrm{l}D / a$ (approximately), where n is any integer except 0, and y is the distance on the screen from the central intensity maximum to the location of an intensity minimum. If Dy is the spacing between two successive intensity minima, it follows that the width of the obstruction (i.e. the diameter of a thin wire or a hair stretched across the laser beam) is given by

$$a = \mathrm{l}D / \mathrm{D}y \;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\;.\; (12.1)$$

The wavelength for helium-neon laser is $6.328 \cdot 10^{-7}$ m. The central maximum will be very bright in this case, and will make it hard to see the other diffraction maxima and minima. You will need to do your measurements in a darkened room. It also will be helpful to observe the diffraction pattern on a light colored paper or cardboard placed so that the central maximum just misses the paper or cardboard.

You can tape a hair across the laser's beam port, or hang it in front of the laser from a support. Determine the thickness as accurately as possible, and estimate the uncertainty in your measurement. Note that you may be able to improve

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your accuracy by measuring the distance between more widely separated diffraction minima. You may want to try measuring the distance between e.g. the two $n = 3$ minima on either side of the central maximum, which will be separated by (6lD / a). In order to accomplish this measurement, you may need to make a hole in your paper or cardboard for the central maximum to pass through without affecting your ability to see the much fainter maxima and minima on either side. Note that your intensity pattern consists of a superposition of closely spaced maxima and minima within a broader pattern of more widely spaced maxima and minima. The more closely spaced pattern results from diffraction by the circular opening which defines the beam size, while the more widely spaced pattern results from diffraction by the hair.

If you can improvise a way of clamping one end of your sample hair to a support and hanging a weight from the other end, you can determine whether tension reduces the diameter of the hair. For several different weights (small enough not to tear the hair) you may be able to obtain data for a plot of thickness vs. tension. Could this be used as the basis of design for an instrument to measure tension?

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Section:____

Partners:____

Laser Applications

Divergence of a Laser Beam.

distance	diameter
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Divergence of beam = _______________________

Diameter on reaching moon = _______________________

Distance where brightness is reduced to 1% = _______________________

Diameter of a Human Hair.

Order of symmetrically placed minima n = _______________________

Separation distance Dy = _______________________

Diameter of hair = _______________________