CONSTRUCTION

LASER
MEASUREMENT
&
BEAM ALIGNMENT

STEVENS POINT
AREA SENIOR
HIGH SCHOOL

INTRODUCTION

The construction industry has quickly applied laser principles to alignment and measurement. Applications have been found in ceiling and underground pipe alignment,surveying, trench digging, tunneling, and varied other applications.

Lasers help us by taking guess work out of positioning large objects in hard-to get-at work places. This module will introduce you to some of the measurement tasks which lasers can do by locating locating a distant object which is the same height as the lasers aperture.

OBJECTIVES

1.   Demonstrate how lasers can be used in the construction field for making precise measurements.
2.   Describe contemporary applications for the laser.
3.   Gain an understanding of how lasers function .

MATERIALS

Heath/Zenith laser and receiver
2 - lens holders with mirrors
4" x 4" card or other stiff paper
Sheet of paper for the target
Block of wood   2"x4"x2"
Masking tape
Small level (optional)

ACTIVITIES

1. Complete lab steps 1 to 10.
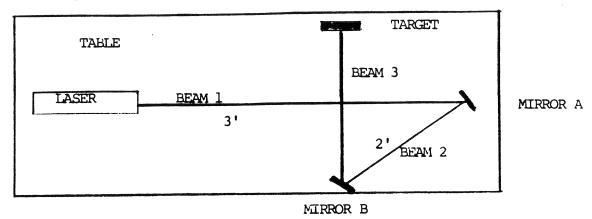2. Read the included references and answer the review
    questions

PROCEDURE

STEPS

1. Lay out the laser and mirrors as illustrated in Figure
Choose a work surface that is flat and stable.

2. Place a temporary target at MIRROR A . Turn on the
laser   and open the aperture.

3. The object here will be to aim BEAM 1 p allel with the
table's surface. Hold the 4x4 card next tc ne lasers
aperture and mark BEAM 1's height above the able
surface.

4. Move the card to MIRROR A's position. Aim the beam at your mark. If BEAM 1 does not hit your mark, place paper shims under the front or rear feet of the laser. Recheck your work carefully.

5. Replace MIRROR A and tape it down. Aim BEAM 2 in the direction of MIRROR B and using the marked card adjust MIRROR A so that BEAM 2 falls in the center of your mark. Recheck your work from the beginning.

6. BEAM 1 and BEAM 2 should now be parallel to the table's surface. If BEAM 3 is positioned so that it intersects BEAM 1, then all three beams will be in the same plane. Since the target may not always be in the lasers line of sight, the usage of mirrors is important in reflecting a beam around corners. The next problem here will be to accurately find the intersection of BEAM 1 and BEAM 3.

7. Aim BEAM 3 close to the target and a red dot will be visible. This is a coarse adjustment.

8. Place the wooden block in BEAM 3's path but not obstruct BEAM 1. See Fig 2 for the location.

9. Gently slide the block forwards to BEAM 1 until a streak of red laser light is visible on its surface. See Fig 3 for details. Be careful not to stop the light completely. Carefully adjust MIRROR B until BEAM 3 intersects with the thin streak of light visible on the block. All three beams are now aligned.

10. Remove the wooden block and check the height of the target beam with your marked card. Does the beam fall on target? The Laser Receiver may also be used to check the beam height.

Instructor sign_____

FIG 1   LASER AND MIRROR SETUP

TARGET

TABLE

BEAM 3
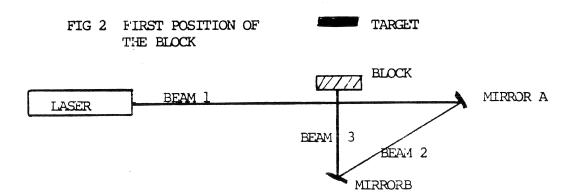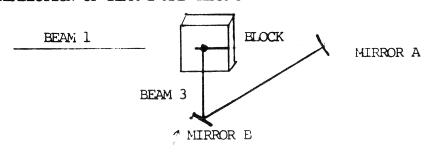
LASER   BEAM 1   MIRROR A

3'

2'   BEAM 2

MIRROR B

FIG 2   FIRST POSITION OF   TARGET
        THE BLOCK

BLOCK

LASER   BEAM 1   MIRROR A

BEAM 3

BEAM 2

MIRRORB

FIG 3   INTERSECTION OF BEAM 1 AND BEAM 3

BEAM 1   BLOCK

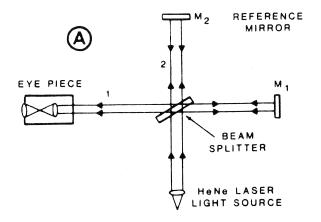MIRROR A
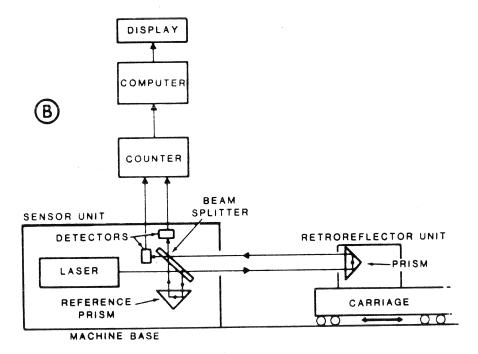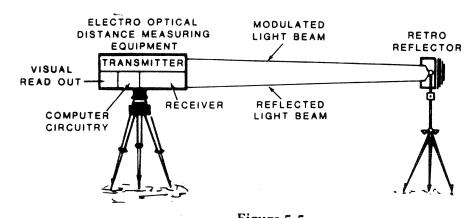
BEAM 3

MIRROR B

SIGHT POSITION

Figure 5-6

Interferometers.

A basic interferometer is shown in Figure 5-6A. It consists of a light source (in this case, a HeNe laser), a beamsplitter, two mirrors, and an eyepiece. The laser projects a beam of light to the beam splitter where it is partially transmitted to mirror M_2 and partially reflected to mirror M_1. The light is then reflected from mirrors M_1 and M_2 back to the beam splitter. The light reflected from the reference mirror is called the reference beam. At the beam splitter, the reference beam is augmented, unchanged or attenuated depending on the phase relationship between the two light beams. The resulting light beam is then transmitted to the eyepiece for viewing.

If the distance from the beamsplitter to M_1 and M_2 is equal, then the two light beams combine constructively and a bright spot appears in the eyepiece. However, if mirror M_1 is 1/4 wavelength farther from the beamsplitter than the reference mirror, the distance traveled by the light beam will be 1/2 wavelength farther. When this happens, destructive interference occurs when the beams recombine and a dark spot appears at the eyepiece. As a result, light and dark fringes are seen in the eyepiece. The greater the difference in distance between the reference mirror and mirror M_1, the greater the number of fringes. Each fringe represents a distance of about 12.45 microinches. By counting the number of fringes, it is possible to position an object with extreme precision.

A second type of interferometer is shown in Figure 5-6B. Although this unit uses prisms, it operates in the same manner as the first interferometer described except that the light beams are now sensed by two photodetectors. These detectors produce a sine wave signal, equivalent to the fringe count, which is processed by the computer. The computer compensates for factors such as temperature, air pressure, and relative humidity, all of which effect the speed of light. When the fringe count is processed, a distance is given on the display.

Light entering the face of a corner reflector undergoes total internal reflection twice and exits parallel to the incoming beam. Thus, the beam returns to the transmitter/receiver. An illustration of a laser transmitter/receiver with associated reflector is shown in Figure 5-5. Generally speaking, laser surveying systems are accurate to within a few hundredths of a foot.

Figure 5-5
Laser surveying system.

Machine Alignment

The alignment and measurement systems just discribed are generally more accurate than the application requires. However, much greater accuracy is required for aligning and adjusting machines such as those used to produce parts for the aerospace or computer industries. To satisfy this need for greater accuracy, designers have developed a specialized system that uses the principles of constructive and destructive interference of coherent light to provide measurement accuracy of approximately 0.000001 inch while measuring distances of up to 200 yards. This device, known as a **laser interferometer**, is so accurate that the National Bureau of Standards has difficulty calibrating it against previous standards of measurement.
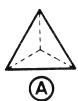
Distance Measurement/Surveying

Precision measurement of long distances has always been a major problem. Triangulation, a method in which you determine distance by means of bearings from two fixed, known points, can be used to determine distance. However, this method is cumbersome and time consuming. Furthermore, if the measured distance is across rough terrain or through dense brush, an accurate measurement is even more difficult.
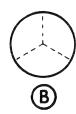
The laser greatly simplifies these measurements. A beam is projected from a laser and travels to a reflective mirror placed at the desired location. At that time, the beam is reflected back to the laser and received by a detector housed in the same case as the laser. A computer circuit analyzes the time it takes for the beam to travel the unknown distance. Since the speed of light is known, it is a simple matter to determine how far a beam has travelled.

With any of these instruments, it is the speed of light that is the critical parameter. A computer performs the calculations and compensates for atmospheric conditions such as temperature and air pressure. Other laser characteristics such as divergence, monochromaticity, and coherence are not of great importance. A HeNe laser is ideal for use in systems of this type for measuring distances of several miles. For distances of less than 2 miles, semiconductor lasers may be used because not as much power is required.

Regular mirrors or prisms are not suitable for use with a laser surveying system. Instead, a special reflector called a **corner-cube reflector** or **corner reflector** is used. This type of reflector is designed to return the maximum amount of light possible with very little regard to its orientation.

Corner cube reflectors can be either mirrors or prisms. If a prism is used, the reflector consists of three mutually perpendicular sides with a hypotenuse face. A view, looking into the corner reflector prism, is shown in Figure 5-4A. The mutually perpendicular surfaces are indicated by dotted lines. When mirrors are used, the corner reflector can have any of the three configurations shown in Figure 5-4.
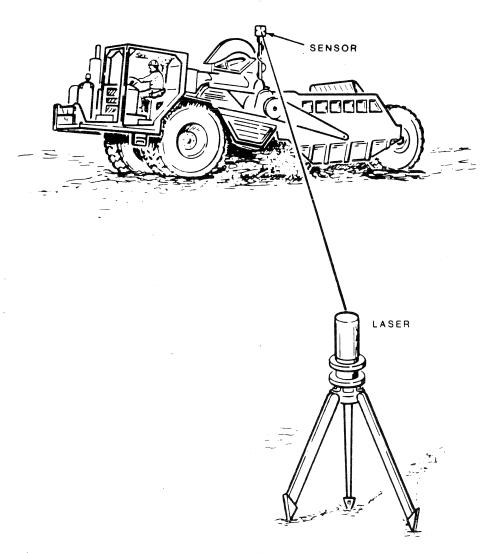

Figure 5-4

Corner reflectors.

The same system can be used in outdoor areas, such as parking lots, when the grade of a surface needs to be leveled or sloped to allow for drainage. The laser is positioned on its mounting tripod in the center of the area to be leveled. A detector, mounted on the grading machine, intercepts the rotating beam. When the beam strikes the detector, the sensor within the detector outputs a signal that indicates whether the surface is above, below, or just at the correct level.

The output of the detector can be used to control the machine; raising or lowering the grading blade as needed, or the output can simply give the machine operator an indication of any surface variations. This application is shown in Figure 5-3. Laser systems used for pipe alignment and building construction are accurate to within a fraction of an inch.

Figure 5-3

Grading a flat surface.

Laying pipe on a slope poses no particular problem when using a laser. By adjusting the laser's mounting bracket, the angle of the beam can be adjusted by the operator to the desired slope. Furthermore, speed and positioning accuracy are dramatically increased by using this system rather than conventional methods of alignment.

Construction Alignment/Rotating Beam Alignment Systems

In Unit 4, we discussed a medical laser system that used a prism or mirror to direct the laser beam. This same concept is used in the rotating beam alignment system. The laser is used in conjunction with a rotating mirror or prism and the beam is directed through a full circle. In effect, the laser beam forms a "light plane" which is ideal for leveling a large area or surface.

Contractors use systems of this design to install hanging ceilings in large buildings. After the ceiling grid is installed, they place magnetic targets on it, then raise or lower the grid until the laser beam strikes the center of the target. When the laser beam strikes all of the targets, the ceiling grid is at a uniform height. In a like manner, the laser can also be used to ensure that walls in large structures are properly aligned. Both of these applications are shown in Figure 5-2.
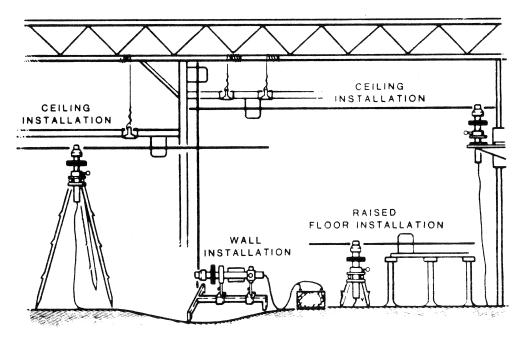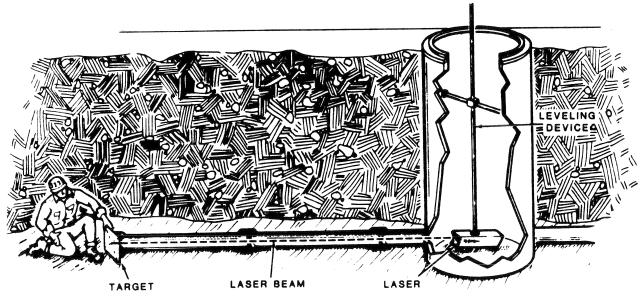

Figure 5-2

MEASUREMENT

In construction applications, the most valuable property of laser light is its directionality. An upcollimator is used inside the laser enclosure to expand the beam diameter and reduce beam divergence. Because the beam does not diverge quickly, it can be used as a reference line over long distances. A low power HeNe laser is most often used because its intensity is low enough to be safe and the beam is visible.

Construction Alignment/Straight Line Projection Systems

Alignment of sewer and water pipes and underground conduit has always posed a problem for the construction industry. For years this task was accomplished using stretched wire and levels. However, this was extremely time consuming and not always accurate.

Now, a laser can be used for this task, with a straight line projection system like the one shown in Figure 5-1. Here, the beam is projected from the laser down the center of the pipe. This beam is then used as a reference to position pipe sections as they are put in place. As additional pipe sections are laid, a target is placed at the end of the each section, and when the beam strikes the center of the target, the construction worker knows that the pipe is aligned correctly.

Figure 5-1

Pipe alignment.

EVALUATION   Lab completed 10 pts
                    Review quest. 10 pts

REVIEW QUESTIONS

     Copy or reproduce these questions on a separate sheet of
paper . Complete and hand in.

1.   Does the beam fall on target?_____
     Instructors signature for step 10_____

2.   How does the laser take the guess work out of pipe
laying?

3.   How could wall tile be accurately aligned 3 feet from
the floor using a laser?

4.   Describe another method by which the intersection of
BEAM 1 and BEAM 3 could be aligned in this experiment?