Invited Paper

Laser experiments for the secondary school classroom

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ABSTRACT

The Laser Applications in Science Education (LASE) project at San Jose State University explores the use of HeNe and visible diode lasers as key teaching tools for an introductory, inquiry-based, pre-college laboratory course in electro-optics. Since 1990, National Science Foundation grants and cost-sharing funds from industrial supporters have allowed over one hundred elementary, middle, and high school teachers to attend workshops designed to show the teachers how to present the course material later to their students as prescribed exercises. This experience then leads the students into open-ended 'menus' of further things to try, and perhaps publish their results in the project journal LASE LOG or compete in science fairs.

This paper describes course content (set experiments and menus) ranging from laser surveying, refractive index measurements, fiber optics, lenses, scanning and chopping systems, irradiance measurements, polarization, diffraction, visible diode laser construction, and holography. The place of such a course, both potential and realized, in secondary education is also discussed.

Key words: laser education, optics education, photonics education, high schools, projects, lab manual

1. INTRODUCTION

There is no doubt that lasers have figuratively and literally etched a niche for themselves in the world around us. Laser applications range from their common place use in CD players, supermarket scanners, light shows, holography, and fiber optic communication systems, to esoteric devices for initiating nuclear fusion. In the middle ground, industrial cutting and etching, medical applications, and general scientific and technological research dominate.

In education, too, lasers now play a dominant role, and in higher education there are many fine examples of optics laboratories which have been developed using the laser as the key instructional tool. At the secondary school level the laser has been slow making its debut, although for many years it has been used for classroom demonstrations.

The Laser Applications in Science Education (LASE) project at San Jose State University has, since 1990, and with financial support from the Teacher Development and Enhancement division of the National Science Foundation, trained science teachers in the use of the laser in the classroom. Summer training workshops, designed to make the teachers confident with a number of activities have resulted in about three thousand students obtaining hands-on experience with laser-driven experiments in the classroom. The added beauty of these activities is that they are likely to be repeated in subsequent years due to the fascinating mix of simplicity , reliability, and sophistication which they entail.

The LASE project started in 1990-91 with seventeen teachers. This was the "research" phase designed to develop activities. In 1991-92 an extra forty teachers were trained using the same activities with some minor modifications. This was the "development" phase. During the summers of 1994 and 1995 the project moved away from San Jose to train an extra ninety six teachers in California, Oregon, Washington State, North Carolina, South Carolina, Massachusetts, and Florida. This is the "dissemination " phase.

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2. THE LASE OPERATION

The curriculum material [1,2,3,4] has been sufficiently well developed to run at least a half semester course. The philosophy driving the LASE project is that of presenting students with a series of prescribed exercises, all using the laser as the key tool, followed by open ended activities to give students a feeling of ownership of the material.

As an example; the rotational speed of a motor is measured by attaching a small masking tape 'flag' to its spindle and measuring the time between light pulse as it passes through a laser beam each revolution. The idea is very simple, and a choice of motors is available at very low cost. As projects, the speed of other items, such as food mixers, drills, roller-blade wheels, can be measured, and the variation of speed with load, and the properties of various loads, such as magnetic damping, can also be investigated. The projects can either be fitted in during regular school hours or as homework assignments. This last point is worthy of elaboration. Bright light emitting diodes (LED's), as well as ordinary light bulbs, can all be used in place of the lasers, and some activities can well be done at home. Add to this the fact that laser pointers, employing visible laser diodes (VLD's), are now quite inexpensive, and could well give the whole educational process in optics a hobby 'flavor', which can only be considered as a healthy move. Admittedly the example of measuring rotational speeds does also require a photo detector and oscilloscope (!) which would limit this activity to the classroom, but other topics described in what follows are not so limited.

Of the seventeen "Topics" described in what follows, all need a laser, but only two really need an oscilloscope, although about three others are embellished by its use. For a class of thirty students, working in groups of two, the total cost with no oscilloscopes is about $5000, and with the oscilloscopes is $9000, an amount which can be reached by running extraneous activities such as bowl-a-thons, sponsored walks, donations from local businesses (for this high profile cause), and so on. Even though this has been stated in a matter-of-fact way, the author appreciates how difficult it is to organize this sort of thing [5], and admires deeply any teacher and students willing to expend energy in such an endeavor.

In what follows the set experiments and manus have been kept brief. For a more detailed description, see Ref 1.

3. THE CLASSROOM EXPERIMENTS

Topic 1. Measuring the size of remote objects.

To a very good approximation a laser beam can be considered as a 'pencil' of light which can run with very little divergence over large distances and so can be used very effectively as a lightweight pointer. Fig.1 illustrates the scheme for measuring the height of a room by measuring the angular elevation of the beam from the horizontal to the top of a wall. The angle A can be obtained either from tan A = rise/run, or by using a protractor, and then using tan A = h/D to find h. It can also be found using the ratio of sides in similar triangles. (The width of the room can be found in the same way).

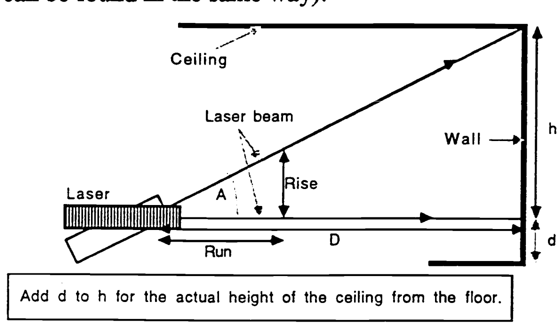


Fig 1. Measuring the height of a room.

Students using this technique have measured the height of buildings, flagpoles, and Ferris wheels, but for such it is best to work at dusk when the beam 'spot' where it strikes the object in question is more easily seen.

Projects.

Perform the same experiment without using a laser.

If you (in California, say) measure the length of the Sun's shadow of a meter stick when the Sun is due south of you, and at the same time a colleague due north of you (Washington state) does the same thing, then how could you determine the radius of the Earth after comparing notes over the telephone?

Topic 2. Laser range-finding.

Fig 2 shows a base-line (b) method of determining distance (a or c) to a distant object. One laser can be used and its position, and beam path, marked on two separate sheets of paper when the beam is striking a distant object. The beam is also marked when the laser is directed from one sheet to the other in order to complete the triangle and get a measure of the angles A and C. The law of sines is then used to find a or c.

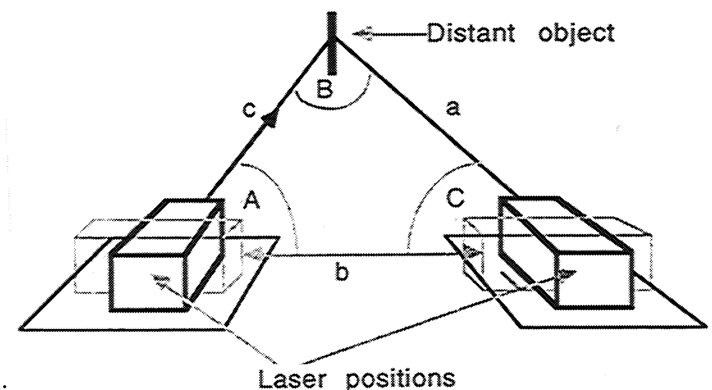


Fig 2. Laser beam range-finding.

Projects.

A fixed laser directed across one sheet of paper to the other can be used, and a mirror placed in turn on each sheet to direct the beam to the distant object. The beam paths can again be marked to find angle A and C.

A mirror on the right-hand sheet and a microscope slide (beam-splitter) on the other will allow manipulation of the reflected beams onto the object. A and C can again be measured, but the operation of bringing two beams together to 'fix' your sighting is quite pleasing.

Accuracy can be tested by having students find distance using first a long base line, and then a short one.

Topic 3. Beam steering by refraction.

The beam deviation action of prisms forms the basis of this activity. In particular, hollow prisms can be constructed as shown in Fig 3 and the refractive index of liquids used to fill them can be measured using the "minimum deviation" method. The angle of minimum deviation can be measured very accurately by triangulation methods again, and the scheme for doing this is illustrated in Fig 4.

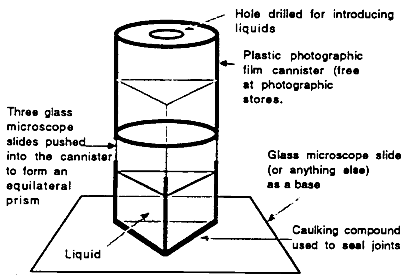


Fig 3 Hollow prism construction.

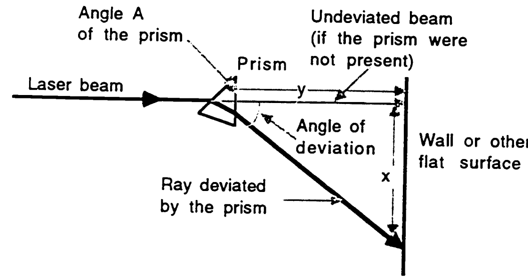


Fig 4. Minimum deviation with a prism.

<u>Projects.</u>

The refractive index of water can be measured and the change of refractive index can be metered as sugar is added. Once a calibration curve of refractive index v concentration is developed, then the concentrations of various 'unknown' samples can be measured.

Semi-circular plastic dishes are very commonly used for refractive index measurements, and they work well with lasers. Angles of incidence and refraction can be measured using a protractor, and refractive indices measured this way. It is interesting to compare the accuracy of this method with the hollow prism method.

Jello can be placed in the prism (or dish) and its refractive index measured when warm, and again after it has set. Bets can be taken as to whether the index will go up or down!

An incandescent bulb and fluorescent bulb, one above the other, can be viewed through the water-filled prism and the spectra (different) can be observed. It would make an excellent project to measure the variation of refractive index with color at this point, or maybe later when the concept of wavelength has been developed.

The minimum deviation of the laser beam can be dramatically shown by placing the prism on a rotating platform and slowly increasing the rotational speed. At low speed the spot will be seen to move to the minimum position, and then 'bounce' back. At high speed this process will show as a line the end point of which is the minimum position.

Topic 4. Beam steering by reflection.

Armed with a front-surface mirror and a protractor, the path of the beam in and off the mirror can be measured, and the law of reflection established. Also, the optical lever effect can be quantified by measuring rotation of the mirror and of the reflected beam. Finally, reflection off a double-mirror, including retro reflection, can be compared with theory (Fig 5).

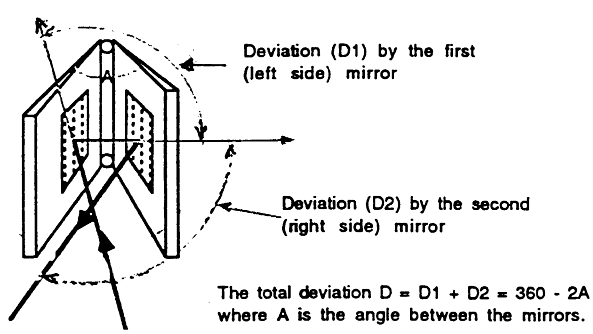


Fig 5. Beam deviations from two mirrors.

Projects.

The LASE maze is an interesting idea. Here a laser beam has to be steered, using mirrors only, through a maze of obstacles to hit an object. The configuration is first presented in diagram form for students to figure out how it should be done using the minimum number of mirrors, and then on the following day they set up their 'solutions', and the laser switched on. It is usually more fun to have students work in teams.

Three mirrors set at 90^o to each other, forming a corner reflector, makes an interesting project. Also, kaleidoscope effects often reveal themselves when working with more than one mirror. A competition on who can get the most interesting effect is fun.

A vertical laser beam shining up onto a small mirror set at 45^o on the axle of a small DC motor (the LASE project usually uses laser mirrors (seconds) supplied by a local company) when spun around generates a horizontal line around the room. Such a system is used in the construction and agricultural industries, and can be studied in the classroom to see just how level the line is. There are reasons why it might not be as level as expected and these reasons can be talked about.

Topic 5. Fiber optics.

The semi-circular dishes described earlier come into their own here to demonstrate and make measurements relating to total internal reflection (see Fig 6). This is followed by the use of single, 1mm diameter fibers, or fiber bundles. The bundles usually require less preparation, but what is actually happening is seen more clearly with a single fiber even though its ends require more preparation. In fact, the filing and polishing of a fiber, and the associated measuring a throughput with the photo detector described later, is an excellent quantitative exercise. Students can be given a homework assignment on how to polish a fiber end with things found around the house to give minimum attenuation of the beam.

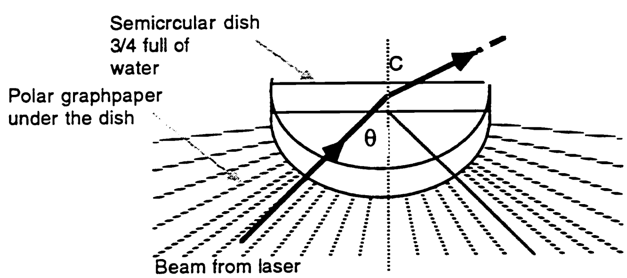


Fig 6. Total internal reflection in a semi-circular dish.

Projects.

Delicate motion sensors can be made using two fibers. One fiber carries the beam in and allows it to shine onto a surface; the other fiber picks up reflected light. As the surface moves away, the amount of light picked up decreases, and the system can be calibrated, using a photo detector, and then used on a piece of lab equipment. An analog meter works well here with the photo detector since a piece of tape can be put over its scale, and a new "distance" scale marked instead.

Topic 6. How quickly does a beam spread out?

The HeNe laser beam diameter remains at between 1 and 2 mm for about 1 or 2 m, but then flares out and increases linearly with distance. It is a very nice reliable exercise to measure the diameter with distance, over many meters, and to plot the results. A target can then be placed at an 'unknown' distance and by measuring the beam diameter, and using the calibration graph, its distance from the laser can be determined.

Projects.

The irradiance of the beam can be metered using a photo detector and, after calibration, distances can be determined using it rather than measuring beam diameter.

The Gaussian profile of the beam can also be plotted using a photo detector, and the curve obtained checked to see if it is indeed a Gaussian.

With the beam shining down a long corridor, as will probably be the case for this topic, some fine diffraction patterns can be observed if objects are place, say, a third of the way down the beam, and the resulting patterns observed at the end. Suitable diffracting objects are sharp edges, the round head of a pin used for displaying insects (Poisson's spot), and heat waves from a candle or a soldering iron.

Topic 7. Photo detector construction.

The photo detectors used are reverse-biased silicon photo diodes or photo transistors. The circuit used is shown in Fig 7. With no light on the detector, there is no current in the circuit. As the light level increases so does the current, and in a linear manner. The current is translated into voltage via the resistor and can be read with a voltmeter or oscilloscope.

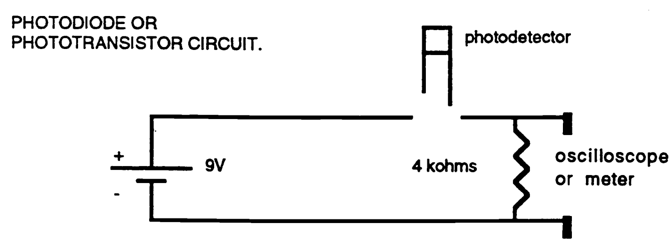


Fig 7. The reverse-biased photo-detector circuit.

Most photo diodes and photo transistors are saturated with a "raw" 1mW HeNe laser beam and a solid 9V signal is obtained even when the beam drops to about 0.3mW. Below this point, however, the voltage drops in a linear manner as shown in Fig 8. This data was obtained by a student at SJSU.

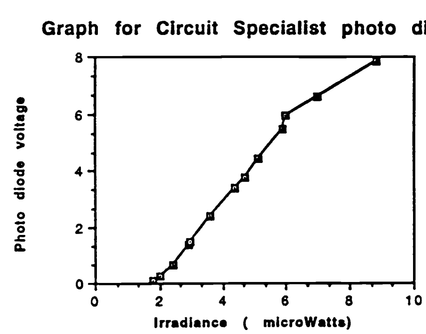
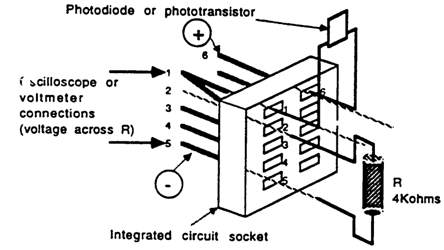


Fig 8. The voltage measured across the resistor of Fig 7 v irradiance on the photo diode.

There are various ways of construction the circuit. Fig 9 shows a) use of an IC socket for dry mounting components, and b) mounting them all on top of a battery.

a)



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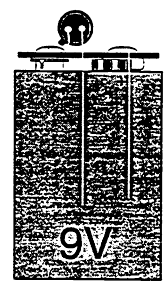


Fig 9. a) an IC mount and b) a battery-clip mount for the photo diode.

Reference has already been made to the use of the detector in earlier topics., and more are to come.

Topic 8. Constructing a "wobbler" scanner.

The scanner is a small mirror attached eccentrically to the shaft of a 3V DC motor so that a laser beam reflecting off it scans around in a circle (Fig 10). It can be used for a number of activities, but the only one described in this topic is determining the rotational speed of the motor as a function of voltage applied to the motor. Fig 11 shows the result of a study at Milpitas HS. Here, a photo detector was placed at a fixed point on the circular sweep and the time measured between pulses seen on an oscilloscope.

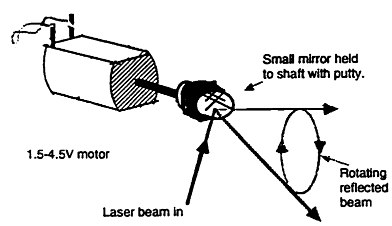


Fig 11. The scanner.

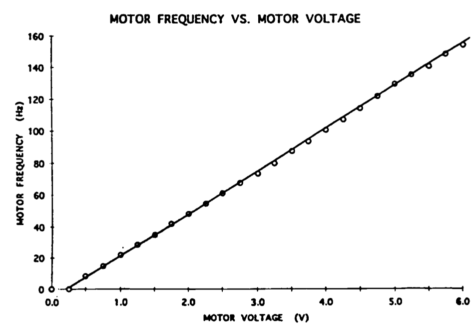


Fig 12. Speed v voltage for a Radio Shack motor.

Projects.

Having the laser beam shine off two rotating mirrors, one after the other, produces some very interesting patterns. Of greater interest is the ability of being able to predict patterns when the voltages supplied to the motors are in various ratios.

Since the scanning circle increases linearly in diameter with distance from the mirror, then this suggests another distance measuring system similar to that of Topic 6 but probably having greater accuracy. In fact the accuracy of the two systems can be compared.

Topic 9. Working with lenses

The arrangement shown in Fig 12 has the scanning beam from the "wobbler" brought back to a point again by the lens. The distance from the mirror to the lens can be called an object distance and that from the lens to the final point, the corresponding image distance. The focal length can be found this way.

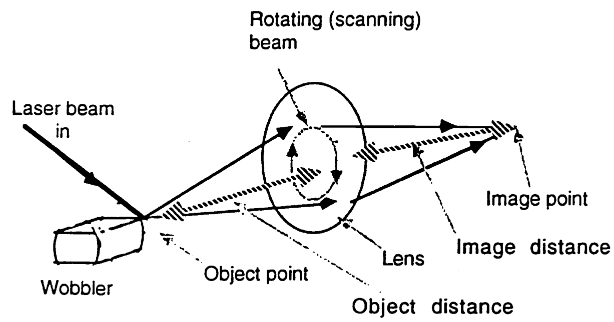


Fig 12. Measuring the focal length of a lens using the laser beam scanner.

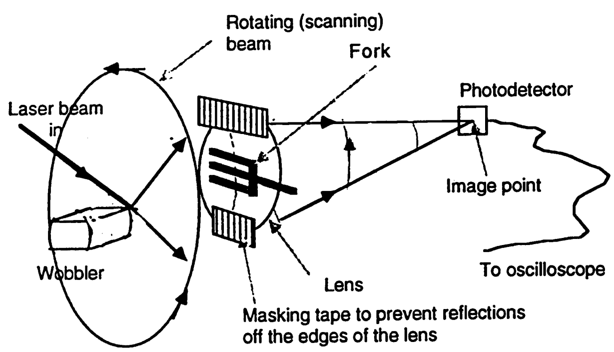
Projects.

Collimated beams, lens systems, and negative lenses can all be studied with this arrangement.

Reflections off lens surfaces can be studied to find surface radii, and the lens maker's formula then used to find the refractive index of the lens.

Topic 10. Bar-code reading.

Scanning a stationary target, such as a fork, with the wobbler beam (Fig 13), and then collecting the light onto a stationary photo detector, gives some very understandable patterns on an oscilloscope (Fig 14). 'Transmission' patterns such as the fork work very well; reflection patters are more difficult to work with.



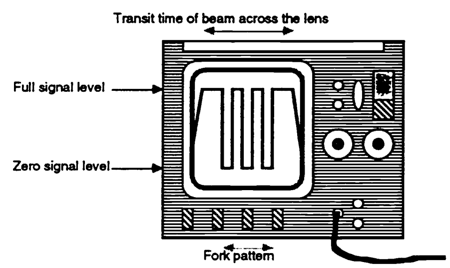


Fig 13. "Reading" a simple pattern with a scanning system. Fig 14. The oscilloscope pattern.

Projects.

Place strips of transparent colored paper or different number of sheets of the same color between the prongs of the fork. This way the pulses will be of different heights and give data on the absorbing power of the various section of the pattern being studied.

Try a reflective pattern (closer to the supermarket situation) as demonstrated by students at Santa Teresa HS, who worked with the fairly reflective pattern on a coke can.

Topic 11. Pulses of light.

This time a card with a slot cut out of it is attached to the shaft of a small motor and spun in a laser beam shining onto a photo detector (Fig 15). An oscilloscope is used to time the pulses from the detector to give the motor speed, or a mirror can be used to reflect the pulsed beam back onto a letter on the disc to make it stationary---stroboscopically speaking.

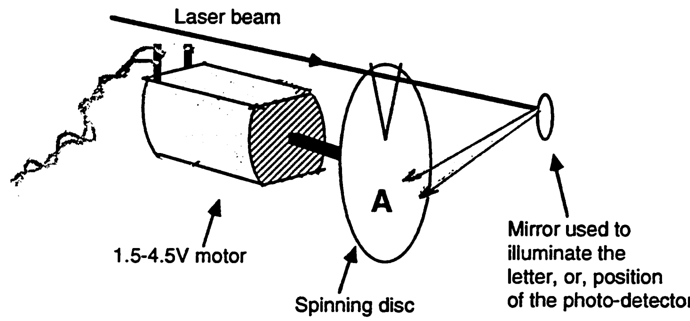


Fig 15. The laser beam "chopper".

Projects.

Food processing systems and fans can all be studied to find their speeds when they replace the motor.

Replacing the cardboard disc with a clear plastic one, sticking to it an opaque letter (Fig 16), and passing various parts of the spinning letter through the beam gives a sequence of patterns on the oscilloscope which can be studied to determine what the letter is. Students like to compete with each other on tasks like this.

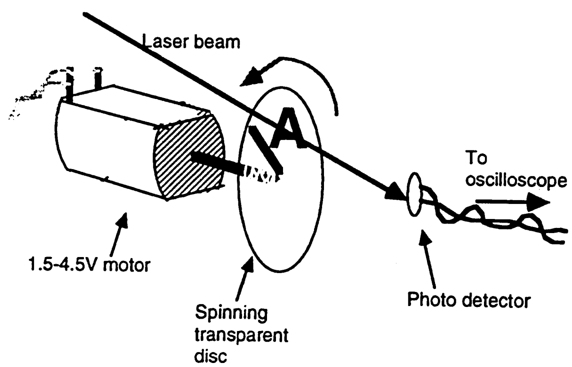


Fig 16. An example of pattern recognition.

Rectangular shaped slots give increasing or decreasing pulse widths as the motor with the spinning disc is raised or lowered respectively (pie-shaped slots do not). In fact , this is a good position metering system.

Topic 12. Absorbing properties of different materials.

If one, two, three, and so on, identical sheets of absorbing material are inserted in the beam then one should measure, using a photo detector and voltmeter, an exponentially decreasing amount of light passing through. This can be done with different colored sheets, and with neutral density sheets.

Projects.

A student at Pioneer HS dripped some blue bathroom cleaner into water in a glass cell and watched as its transmittance got weaker and weaker. Assuming his drips were being produced at a constant rate, his detector voltage v time graph could be used for measuring time by looking at voltage showing on a meter.

Scattering experiments follow the same pattern as the absorption one just described. Here drops of (diluted) paint can be dripped into water instead of clear, but colored liquid.

Reflection experiments are much the same too. The reflectance of mirrors and other items can all be measured and compared. The variation of reflectance with angle of incidence is particularly interesting when studying laser dielectric mirrors, and glass surfaces.

Topic 13. Polarization.

If a plane polarized laser is used, then the law of Malus can be used to check the linearity of the photo detectors. (For the LASE Project we state categorically that they are so, having checked them against calibrated meters in our laboratories). Also Brewster's law can be investigated.

It is best to retreat to a conventional light source if only unpolarized lasers are available since their mode-hopping causes the effect of partial polarization with its plane of polarization slowly rotating (period about 1 min), and so if a polarizing sheet is first used to polarize the beam, large time -varying signal variations are seen which interfere with any experiment.

Whatever form of laser is available the experiment illustrated in Fig 17 shows how polarization by scattering can occur. The figure is for an unpolarized laser, and the fact that the scattered light is plane polarized as shown can be checked with a Polaroid sheet. If the laser is plane polarized (vertically say) then when viewed from above, no light will be seen. The polarization of light scattered from various parts of the sky can now be checked and comparisons made with light scattered from the tank.

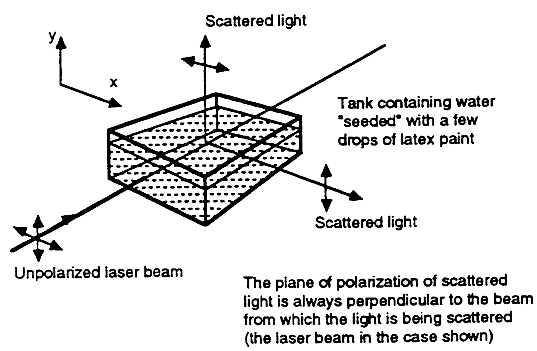


Fig 17. Polarization by scattering from a "seeded" liquid in a tank.

Projects.

Liquid crystal display cells are easy to come by and can be stripped of their mirror and one polarizing sheet. Light from a plane polarized laser can be shone through a segment activated using the sinusoidal output of a function generator, and the irradiance variation metered as the light emerges from the polarizing sheet face. At low frequencies (<1Hz) the large liquid crystal molecules can keep up with the changing field, and the sinusoidal output has a large amplitude. At higher frequencies the response drops off and the amplitude drops correspondingly. In this way a frequency response curve can be generated.

If a function generator is not available, then the "optical" frequency generator depicted in Fig 18 can be constructed!

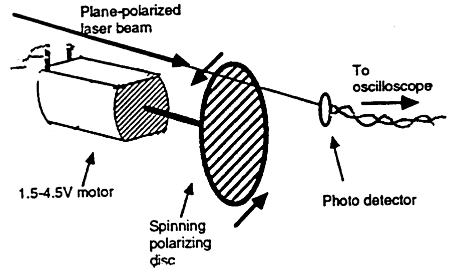


Fig 18. A system for obtaining a sinusoidal output from a photo detector.

Topic 14. Interference.

Students like making their own pieces of apparatus, and if a microscope slide is covered with soot, by running it a few times through a candle flame, and two pins held in contact are run across it to produce two 'slits', then Young's double slit experiment can be repeated to find the wavelength of the laser (Fig 19). The slit separation can be found by placing the slide on an overhead projector, and measuring the separation of an image of the slits on a distant screen. Knowing the magnification , after projecting the image of a transparent ruler and performing some measurements and calculations, then the actual slit spacing can be found.

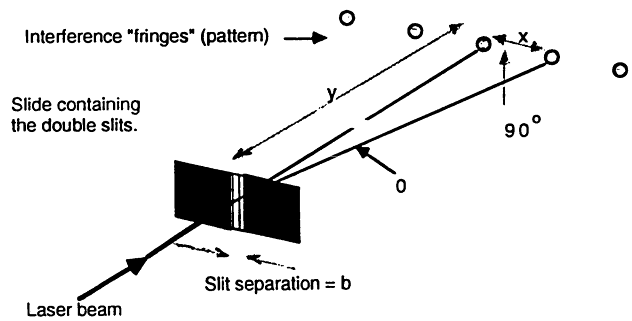


Fig 19. A double slit interference experiment.

Projects.

If an expanded beam is made to reflect off a microscope slide or cover slip onto a far wall, the slide outline will be seen to be covered with fringes formed by the interference of light reflected from its front and back surfaces. The regularity of their form will be an indication of the uniformity of the slide material and thickness. Slides from different manufacturers can be studied.

If a soldering iron is placed in contact with the slide and switched on, then a time-varying distortion of the fringes will be observed.

A similar experiment to this involves using a soap film on a rectangular frame instead of the microscope slide. In this case evaporation of the film and gravity play large parts, the former causing the fringes to vary with time.

If a raw beam is directed through a small hole in a sheet of white paper onto a back-surface mirror oriented to send the beam back to the hole, then if one breathes heavily on the mirror surface a perfectly circular fringe pattern will be seen on the sheet of paper. This pattern is due to the interference of a) the component of light penetrating the front surface without scattering and scattering on the way out, and b) the component of light scattering at the front surface but not scattering on the way out. The mathematics itself is a project, but the formula linking the various parameters of the system is $n = d \tan\theta / \lambda$ where n is the refractive index of the glass of the mirror, d is its thickness, λ is the wavelength of the laser, and θ is the angle subtended by the radius of the first bright interference ring at the mirror.

Speckle is another interesting interference effect. If an expanded beam is projected onto a sheet of paper and a student with her or his head fixed in position views it as a partner raises on lowers it, then the pattern moving with or against the motion is an indication of long or short sightedness. Students with known vision problems can be 'used' to determine which case obtains, and the effectiveness of their corrective eye wear, when replaced, can be evaluated.

Topic 15. Diffraction.

Diffraction gratings form the basis of this activity. They can be purchased or constructed as part of the holography activity, and calibrated using a HeNe laser. They can subsequently be used to measure the wavelength of light emitted by a laser pointer, LED's. fluorescent tubes, and to observe the absorption of various color filters.

Projects.

Measuring the diameter of human hair makes an interesting experiment and is illustrated in Fig 20.

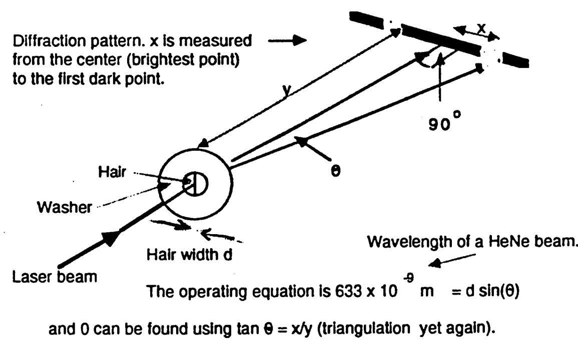
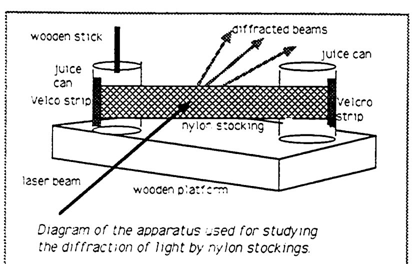


Fig 20. Measuring the diameter of a human hair by studying diffraction patterns.

Students at San Mateo HS measured the mesh spacing of panty-hose by studying the diffraction of light through selected samples. Fig 21 shows their apparatus and results.



DATA TABLE

Type of nylon	Distance between dots (x) Trial 1 (cm)	Trial 2 (cm)	Trial 3 (cm)	Avg. (cm)	Fiber spacing (m)
Classic Rib	2.3	2.3	2.2	2.27	2.26×10^{-4}
Daysheer	2.4	2.0	2.2	2.20	2.40×10^{-4}
Fishnet	1.1	1.1	0.6	0.93	5.58×10^{-4}
Heathers	1.5	1.3	1.1	1.32	3.90×10^{-4}
Shetland Opaque	1.1	1.2	1.1	1.15	4.54×10^{-4}
Ultra Ultra	2.3	2.5	2.3	2.37	2.20×10^{-4}

Fig 21. Measuring the mesh spacing of panty-hose by diffraction.

A scanner can be made by spinning a piece of diffraction grating attached to the axle of a motor as in Topic 11. A series of circles are generated in this case due to the various orders.

CD's make excellent reflection diffraction gratings, and when probed with laser light of known wavelength, the track spacing can be found.

Topic 16. Holography.

This is probably the most exciting for school students. Fig 22 is a plan view of the contents of a sand box with bricks to keep the laser and object from making direct contact with the sand and hence avoiding dust contamination. It shows a simple transmission hologram arrangement which resembles a Lloyd's mirror experiment. The images of such holograms can have great depth. A similar arrangement is used for making white-light reflection holograms. Both arrangement require identical exposure times (12s using a 1 mW laser expanded to a 10 cm beam diameter), and development (1 min in Kodak D19 developer, and about 45s in a potassium dichromate bleach, rinsing well between and after each solution).

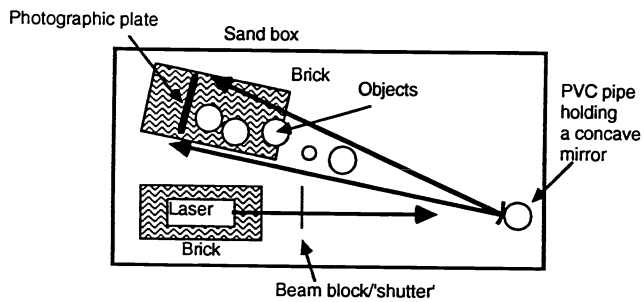


Fig 22. A plan view of a sand-box system for making transmission holograms.

Projects.

If the objects used when making the transmission hologram are replace with a front surface plane mirror, then the reference and object beams produce straight fringes, and after processing they will act as a sinusoidal diffraction grating of very high efficiency. This can then be used in the topic on diffraction.

If the arrangement shown in Fig 23 is used, then this results in a transmission hologram where the image is seen 'full face' rather than by having light glancing off it as in the hologram first described.

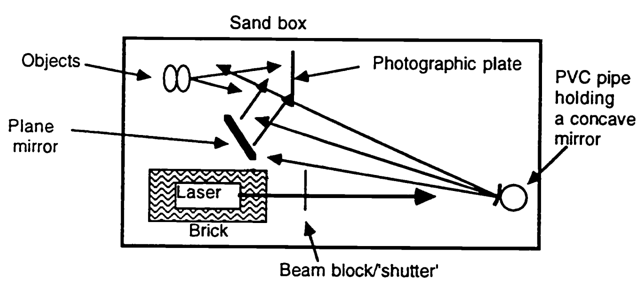


Fig 23. Standard transmission hologram-making system.

A student at North Salinas HS was able to make a holographic optical element (HOE) by replacing his object by a lens focussing the object beam beyond the photographic plate. Upon reconstruction, his hologram was able to image any object and obeyed the lens equations, and so acted as a fully functional lens.

Students from Santa Teresa HS made double exposure holograms of a steel ruler in contact with a soldering iron. Between exposures the iron was switched on for a few seconds. The resulting hologram showed interference fringes indicative of the strain of the ruler as the iron bit expanded.

Topic 17. Visible Laser diodes.

Visible laser diodes can be bought for about $10 and when operated in the circuit shown in Fig 24, can be run as an LED (V<8V) or as a laser (V>8V). The beam is highly divergent, but collimating lens are usually supplied to roughly collimate the beam. It is quite exciting to see the laser action starting, and these lasers without the collimating lens are great for viewing transmission holograms.

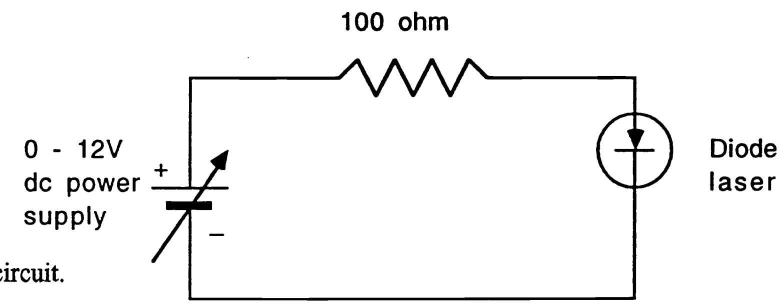


Fig 24. A visible laser diode circuit.

All teachers attending current workshops are given one of these lasers and they first get familiar with their circuit by running LED's in place of the laser. It is important that the current be carefully watched to prevent burning out the lasers, and for this the voltage across the resistor is metered. Threshold for lasing is about 65mA, and a good running current is 75mA. Students at Harbor HS in Santa Cruz obtained the graph of Fig 25 for this paper.

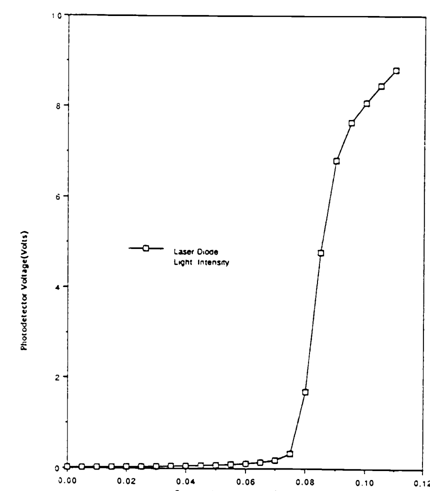


Fig 25. The light emitted by a visible diode laser v current.

Projects.

The polarization, wavelength, and beam divergence (giving the dimensions of the rectangular emitting area) can all be quantitatively studied.

Using the laser (or the LED's) with a fiber is very close to the real use of fibers. Also, the low voltage supply makes this a safe laser for connecting to a signal carrying voice or music patterns. The Project is just moving into this communications phase, picking up on ideas developed elsewhere.

4. SIGNIFICANT FINDINGS

The following "Significant findings" should be considered carefully if a project such as LASE be attempted elsewhere.

Significant finding #1. Local electro-optics companies are very willing to help by allowing LASE teacher meetings on their sites, and by donations of money and equipment. The companies, and also professional societies, who have helped are Coherent, Edmund Scientific, Hewlett Packard, IBM, Intel, the Laser Institute of America, the Laser and Electro Optics Manufacturers' Association, Liconix, the Optical Society of Northern California, Spectra Physics, and Uniphase. All can identify with the subject matter, and see a way they understand where industry can help local schools.

Significant finding #2. Some teachers are more active than others in adopting new curriculum material. This fact is compounded by schools not having the equipment necessary for LASE activities. Never-the-less to date about 3000 students have been exposed to this material in the San Francisco Bay area, and the graph of Fig 26 shows the number attempting each topic between 1991 and 1994. An outside evaluator (Dr. Steve Schneider of Woodside Research Consortium) summarized the program: "There was a significant and positive impact on the optics instruction and activities in the LASE participants classrooms. For teachers without formal optics background, the impact on their content and comfort in teaching optics was dramatic. Teachers who had never taught optics were including optics in their courses after the institute. There was a noted statistically significant and positive impact on content comprehension, and willingness to teach optics topics between pre- and post-institute responses for all groups of teachers". The teachers referred to were those who attended the 1994 West Coast Workshop Series (4 workshops, 41 teachers).

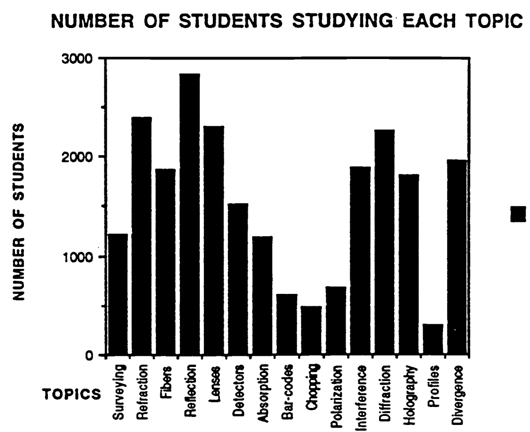


Fig 26. The number of students attempting different Topics. (1991-94)

Significant finding #3. Publication of the project journal LASE LOG resulted in ten issues between 1991 and 1995. Each contained about eight articles by students, and were distributed to 150 schools and local companies, mainly locally. Many students were obviously receptive to the hands-on nature of the project, and also many saw the value of getting their names in print as an aid when applying to the college of their choice. In addition, the Optical Sciences Fairs of Northern California 1992, 1993, and 1994 held at San Jose State University, and sponsored by SPIE, were completely dominated by LASE students. Of the approximately hundred students who submitted exhibits, about ninety were from LASE schools, and all major prizes went to these students.

Significant finding #4. Treating the schools in a professional manner seems to have rewards. Students and teachers respond well when asked to do specific tasks if the tasks are themselves significant. One example of this is illustrated by Fig 27 which shows the front page of one of the LASE LOG issues. Earlier, identical samples of a glasss plate kindly given by Schott Glass Co. were sent to a number of schools for measurements. Specifically, students were asked to measure such parameters as density, refractive index, reflectance, and the angle between surfaces. They were given two weeks to do this, and the results occupied a completes issue of the journal. A second example relates to this paper.

A number of schools were approached to take measurements and submit results to illustrate the Topics section. They all treated this very seriously and many of their results have been used in this paper.

LASE LOG

A Cooperative Project of the National Science Foundation and San Jose State University

THE PURPOSE OF THIS NEWSLETTER IS TO FACILITATE INTRODUCTION OF LASER APPLICATIONS IN SCIENCE EDUCATION

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• Principal Investigator: Gareth Williams • Program Assessment Consultant: Don Pernn • Publication Production: Morning Shu, SJSU Faculty Desktop Publishing Lab •

STATEMENT OF PURPOSE

LASE LOG is the newsletter of the LASE Project (Laser Applications in Science Education). It contains articles submitted by high school physics students and teachers, or articles of interest to them. The LASE Project itself, which started with a summer workshop in 1990, is a study of the feasibility of teaching optics using the laser as the main teaching tool, and is supported by the National Science Foundation and San Jose State University.
This Publication is oriented towards science education and contains articles based on actual studies by the authors. Each study will be considered to be "original research" for the purpose of publication.

If you wish to submit an article for publication, wish to receive free issues of LASE LOG, require further information on the program, or wish to participate in next year's NSF funded LASE workshop, please contact Dr. Gareth Williams, LASE Project, Physics Department, San Jose State University, One Washington Square, San Jose, CA 95192. (408) 924-5248.

Editor's Note: A majority of the articles appearing in this issue of LASE LOG deal with measuring properties, particularly optical, of identical glass blocks kindly supplied by Schott Glass Technologies Inc., Fullerton, CA. It was decided by the Editorial Board to present the articles as they were received. An article discussing the results will appear in the next issue of LASE LOG. The Editorial Board wishes to thank all teachers and students for a job well done, and congratulates them on the publication of their articles.

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Financial support for the publication of this issue is provided by LEOMA, the Laser and Electro-Optics Manufacturers' Association, 123 Kent Road, Pacifica, CA 94044.

Fig 27. The cover page of one issue of LASE LOG, journal of the LASE project.

5. CONCLUSIONS

The use of the laser in the secondary school classroom is an exciting way of teaching optics. It does not merely have to be used for demonstration purposes, but can become the focus of serious hand-on activity if enough equipment is available.

The equipment breaks down into two categories. Expensive and inexpensive. This is all relative to what the average school budget will allow, but the lasers, oscilloscopes, and voltmeters used are the expensive items. The photo diodes, circuit elements, motors, batteries, lenses, diffraction gratings, holographic film, mirrors, tanks, optical fibres, and polarizing and absorbing filters are all inexpensive. We obtain the latter items from supply houses such as Arbor Scientific, Digi-Key, Edmund Scientific, Integraf, Radio Shack, and Sargent-Welsh (3). Many of the items can be bought more inexpensively at local surplus stores, but their availability is variable, and since the LASE project is now national, it is better to pay extra for a reliable supply available to everyone.

Recommended lasers are either new HeNe, 1 mW units from Uniphase (about $200) , similar power used lasers from Gedeon Designs (about $50), or diode laser pointers from Omnitron (about $30 in kit form). All have been used in the Project, and the used lasers have performed well. Be warned though that the diode lasers are not suitable for holography, nor do they have have very clean beams for profile studies.

The topics described in this paper would cover about seven weeks, but with some extra electronic exercises and light communication activities, it could easily be extended to cover a whole semester. This "photonics" offering could be presented at a variety of levels, but probably the best level would be between an introductory physics course (sophomore) and an AP course (senior). It could be used as an inducement to the younger students, and a source of project work for the older ones.

5. ACKNOWLEDGEMENTS.

First and foremost I would like to thank all the teachers and students who have made this project so very enjoyable and rewarding both for themselves and the author. In particular the author would like to commend those teachers who have presented their results at local professional meetings, and at the International Congress on the Applications of Lasers and Electro-Optics (ICALEO) in 1992 and 1993 in Orlando, Florida.

Thanks also to the National Science Foundation in particular, San Jose State University, the Deans of the College of Science, the the Physics Dapartment for financial and support help to run the LASE project. In addition the following professional societies and companies have helped monetarily and with equipment; Coherent, Edmund Scientific Co., Hewlett-Packard, International Business Machines, Intel, the Laser and Electro Optics Manufacureres' Association (LEOMA), the Laser Institute of America, the Optical Society of Northern California, Liconix, Spectra-physics, and Uniphase.

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