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EE 428/551 Optics

Laboratory Manual

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Introduction

The Optics Laboratory is intended to provide the student an opportunity to gain a deeper understanding of optics and photonics through hands-on experience.

Optics is a broad and diverse field. During a study of optics, the student is faced with the challenge of absorbing numerous new concepts. The experiments in this laboratory are designed both to help you comprehend these concepts better, and to provide a stimulus for further study. During the course of these experiments, you will not only gain a fuller understanding of the subject as presented in class, but also develop skills essential for experimental work in optics. The experiments are simple, yet fundamental in nature. This helps the students to concentrate more on the ideas and concepts, and less on experimental technicalities. As a result, learning optics becomes an enjoyable experience.

Laboratory Procedures

The following guidelines are established to assure that the experiments run smoothly.

You are expected to read the relevant experiment in this manual prior to coming to the laboratory. You should also prepare yourself by reviewing the material covered in class and by thinking about the objectives of each part of the experiment. Some experiments require you to do some preliminary work, such as deriving expressions that you will need or plotting some graphs, *before* coming to the laboratory. Such preliminary work is essential for the experiments to be educational. Preliminary work is highlighted with **bold type** in this manual. Other than this preparation, the work required for each experiment is limited to the duration of the laboratory hours. You will perform the experiment and write a report as you go along. The reports will be handed in to the laboratory assistant at the end of the laboratory session.

Each laboratory group consists of two students. Two groups can perform experiments at the same time. A laboratory session is limited to a maximum of three hours. However, some experiments may take less time; you may leave as soon as you finish the experiment and hand in your report.

Each student in a laboratory group will write a separate report. In your report, you should write about everything that you think is relevant to the experiment. The following are some guidelines for the preparation of laboratory reports:

- Show the derivation of all expressions used in the experiment (but not given in the book). These derivations should be done *before* coming to the laboratory.
- For each part, clearly indicate what you have done. Give a sketch of the experimental setup. Explain the measurements taken. Tabulate all raw and processed data clearly.
- Write down all your observations, results, and conclusions. Answer all the questions that are posed in this manual.
- Be clear and organized in the presentation of your work. Use graphical tools where necessary.

You are encouraged to write your report as you go along rather than after finishing the experimental work. Think of the report a your *lab notebook* that you are writing for yourself and your supervisor. You may need to bring graph paper, a calculator, and your textbook to the laboratory. There is a computer and a printer in the laboratory that you can use for doing quick calculations and generating graphs.

Before you leave the laboratory, make sure that all the equipment that you have used are placed back in their boxes.

Safety

Certain precautions should be followed to assure the safety of the students and the equipment in the Optics Laboratory.

Laser safety

The Helium-Neon laser used in the Optics Laboratory produces an intense beam of light. (The intensity of the laser beam is several orders of magnitude brighter than the sun.) To avoid injury to yourself or others, extreme care must be taken when using the laser.

The power level of the lasers used in the Optics Laboratory is approximately 0.8 mW. This is a relatively low power level for lasers. At these power levels, the laser beam will not harm the skin even upon direct exposure. However, the human eye is much more susceptible to injury by laser light. Direct exposure of the eye to the laser beam may result in injury. This is because the lens of the eye focuses the beam to a very small spot on the retina, the light sensitive layer at the back of the eye. Upon direct exposure with the beam, all the power of the laser is concentrated to a very small area on the retina, resulting in very high intensities that may lead to a local burn. Such burns in the retina may cause a degradation of vision, depending on the exact location and size. However, these hazards are easily avoided by following simple precautions.

These precautions should be followed at all times to insure the safety of yourself and others working in the Optics Laboratory:

- Never look directly into the laser beam.
- Never look directly into specular (mirror-like) reflections of the laser beam.
- Do not wear any objects on your hands and wrists that may cause specular reflection of the laser beam (such as watches or jewelry).
- Always be aware of the location of all the beams, including various low power stray reflections.
- Do not let the laser beam or any of its reflections leave the experiment table unless required by the experiment.
- Keep all the beams in a plane parallel to the experiment table.
- Do not bring your eye level down to the plane of the laser beam.
- Block the laser beam with a dark opaque object when the beam is not in use.

Laser light scattered by rough surfaces such as paper is completely harmless to the eye at low power levels. However, it is still a good idea not to stare at bright diffuse spots for a long time.

Equipment care

The equipment in the Optics Laboratory are expensive and delicate. Care should be taken to assure that the equipment is not damaged or deteriorated in any way. Precautions to avoid damage to specific components and instruments are listed with the instructions in the **Equipment** section. Some general precautions that have to be followed are stated here.

All optical surfaces are susceptible to be damaged easily. Some optical components have delicate optical coatings on them, and others have plastic surfaces. Fingerprints and scratches are the most common sources of damage. They may both degrade the performance of an optical component irreversibly. Certain precautions pertaining to all optical surfaces should be followed at all times to insure the safety of the optical components.

- Never touch optical surfaces. Hold all components by their side.
- Never drop optical components. Be gentle and careful. Do not rush.
- Do not lay down components on the table where they can be easily knocked away.
- Always place an optical component in its mount *after* you have secured the mount on the optical bench.
- Always put the components back to their case or box when you are done with them.
- Follow beam paths with a piece of paper, not with your hands or with something that may scratch optical surfaces upon accidental contact.
- If an optical surface gets dirty (fingerprints, dust, etc...) or scratched by accident, do not try to clean it. Report to the assistant immediately.
- When in doubt about the use of a particular component, always ask the laboratory assistant for help.

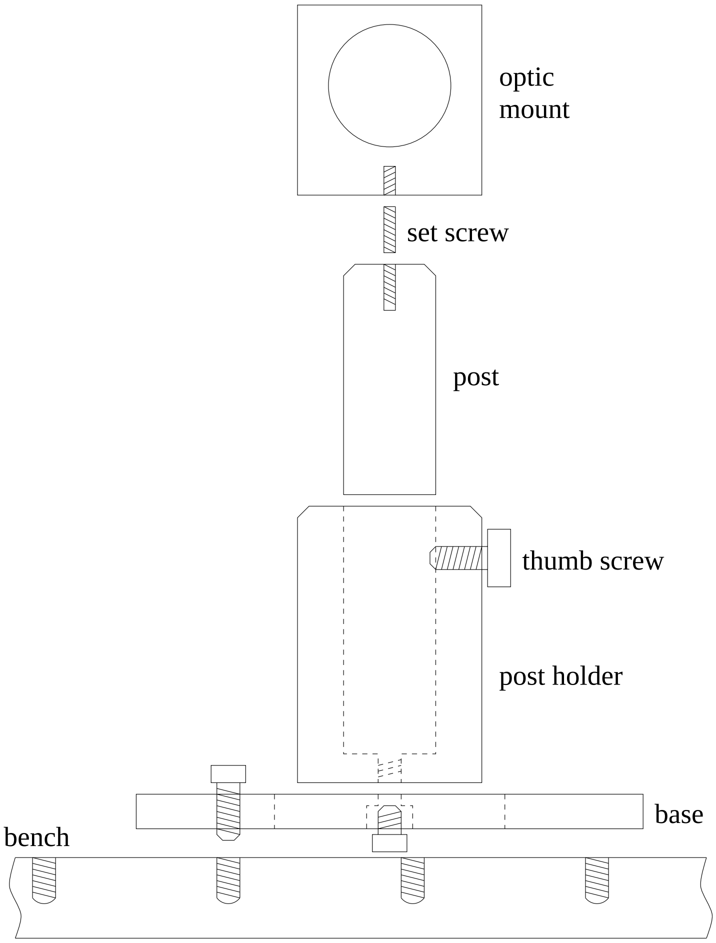
Care should be exercised with opto-mechanical equipment as well. Some of these equipment have delicate mechanical parts that can be easily damaged.

- Do not drop opto-mechanical components.
- Do not force any part of an opto-mechanical component.
- Do not over-tighten any screws. A controlled amount of torque is usually enough to secure a screw.

Equipment

Opto-mechanical equipment

The opto-mechanical equipment in the laboratory provide a system for holding, positioning, aligning, rotating, and translating optical components. The figure shows a typical arrangement of opto-mechanical components aimed at positioning an optic on the optical bench. Please note that the opto-mechanical equipment in the laboratory have dimensions and standards that are mostly in English units; i.e. they are not metric.

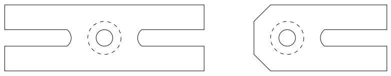


Screws and wrenches There are two boxes with a variety of screws. Two different thread sizes exist for the screws: 1/4–20 (large diameter) and 8–32 (small diameter). (Some optical mounts have 6–32 size set screws as well.) Cap screws have a head and a hex socket. Set screws do not have heads. Allen wrenches and ball drivers are used with the hex sockets.

Wrench set A wrench set with different size Allen wrenches are provided. Always be careful to use the correct size wrench. Otherwise, the tip of the wrench may be damaged. Do not over-tighten any screws. A controlled amount of torque is usually enough to secure a screw.

Optical bench The optical bench provides a platform for positioning the optical components used in the experiments. The bench has threaded holes in a rectangular array with 1 inch (2.54 mm) spacing. The threads are for 1/4–20 screws.

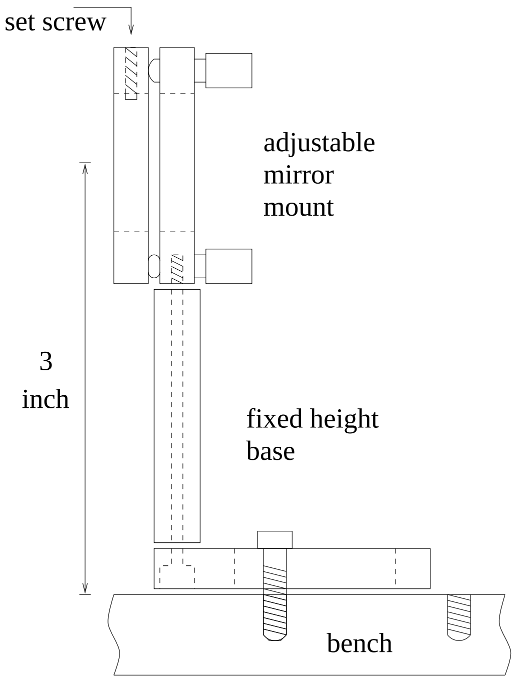
Bases Bases are either screwed directly to the optical bench, or secured with a clamp. Short bases are available in situations where space is limited.



Post holders Post holders are screwed to the bases. They can hold a 1/2 inch thick post at an adjustable height. The thumb screws on the post holders are used to secure the post at the desired height. Do not over tighten the thumb screw. Post holders can also be screwed onto the rotation platform and the translation stage. Six post holders are available at two different heights.

Posts Posts are steel rods with threaded holes on either side. One side has 1/4–20 threads, and the other side has 8–32 threads. These threads are used to connect the post to an optic holder or mount with a set screw. After this, the post goes into the post holder. There are 12 posts of various sizes available for each group.

Fixed height mounts There are four fixed-height bases for 3 inch and one for 2 inch beam heights. Adjustable mirror mounts are connected to these fixed height bases as shown in the figure with long 8–32 screws from the bottom.

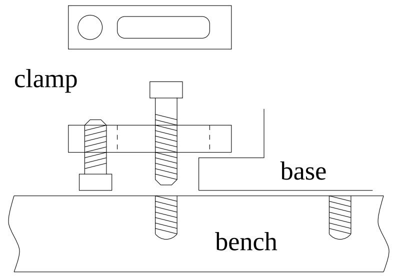


Optic mounts There are a variety of mounts for holding different optical components:

- Adjustable mirror mount (4): These mounts are for holding 1 inch optics. The pitch and yaw angles can be adjusted using the knobs at the back. The optic is secured in its position with a nylon tipped set screw.
- Small adjustable mirror mount (2): These mounts are for holding 1 inch optics. The optic is placed in a metal holder which is then secured to the mount with a set screw. In the experiments these mounts are used to hold the mirrors that steer the laser beam.

- Plate holder (1): This is used to hold thick optical components. Be careful not to tighten the retaining screw too much, as this may damage the optical component.
- Slide holder (2): These are used to hold optical components that are mounted in slide frames. Be careful while inserting the slides into the holder.
- Fixed optic mount (3): These mounts hold 1 inch optics with little mechanical obstruction, but have no adjustments.
- Threaded optic holder (4): These are used to hold optical components that are mounted in cylindrical threaded housings, such as the lenses in the lens set.

Clamps Clamps are used to secure the bases on to the optical bench. Using clamps allows more freedom in the positioning of bases. Clamps are used as shown in the figure.



Translation stage The XZ translation stage provides accurate linear motion in two dimensions. The micrometers on the translation stage provide distance readings in 10 μm increments. The total range of the micrometers is 25 mm.

Rotation stages Two rotation stages provide calibrated angular motion around an axis that is parallel to the beam. One of the stages is dedicated to the 42 mm diameter polarizers.

Rotation base The rotation base provides calibrated angular motion around an axis that is perpendicular to the beam.

Angle measurement rotation base The angle measurement rotation base provides both calibrated angular motion and a mechanism for measuring the angle of a reflected beam. This base is used with magnetic component holders.

Iris A variable iris serves as a variable diameter circular aperture. Irises are also useful as alignment tools and to block unwanted stray reflections. Be careful not to force the iris at the smaller end of its diameter range.

Right angle post clamp The right angle post clamp can be used to connect two posts at right angles.

Ruler A steel ruler with both mm and inch units can be used for measuring distances up to 15 cm.

Optical components and instruments

Helium-Neon laser The Helium-Neon laser produces an intense beam of light. Observe the safety precautions outlined on page 2 at all times to avoid injury.

The Helium-Neon laser operates at a wavelength of 632.8 nm. Its output power is nominally 0.8 mW. The beam has a Gaussian (TEM_{00}) transverse profile and is linearly polarized. The He-Ne laser has a power supply with an on/off switch and indicator light on.

The laser takes some time to warm up after first being turned on. (Approximately 15 minutes.) The output power level may fluctuate during this time. At the beginning of the experiment, make sure that the laser is properly mounted before turning it on. Leave the laser on throughout the experiment. Use an opaque object to block the beam when not in use.

Mirrors Four dielectric mirrors and two aluminum mirrors with flat surfaces are provided. The dielectric mirrors are broadband visible mirrors designed to be used at 0–45° incidence angle. An additional aluminum mirror mounted on a magnetic mount is also provided.

Lens set A set of lenses that are mounted in cylindrical threaded housings is provided. There are fourteen positive and two negative lenses in the set.

Polarizers Two polarizing filters are provided. These have rotating threaded housings that fit one of the rotation stages.

Waveplates The half-wave and quarter-wave waveplates (retarders) operate at 633 nm.

Beamsplitter A 50% dielectric beamsplitter operating at visible wavelengths is provided. The beamsplitter is designed to work at 45° incidence angle.

Compensator plate A blank glass plate that has the same dimensions as the beamsplitter provides a method to compensate for the thickness of the beamsplitter in an interferometer.

Monochromatic lamp A green monochromatic light source is provided.

Incandescent light source The incandescent light source is a regular light bulb. The bulb filament temperature is 2700 K. The spectrum of the emitted light is that of a blackbody radiator at this temperature. The light source has an on/off switch on the back panel. There is a knob on the top to align the bulb filament.

Optical power meter The power meter is used to measure the light power. It consists of a silicon photodiode, an amplifier with different scales, and a readout from a volt meter. A He-Ne filter can be used to block the room lights when measuring laser light. Be sure to turn off both the volt meter and the detector when you are done using the power meter.

Diffuser The diffuser provides a means of obtaining diffuse light. It can be used both with the laser and the incandescent light source.

Crossed arrow target The crossed arrow target has perpendicular arrows of different widths with a circle concentric on the crossing points of the arrows. The larger arrow contains a 15 mm scale.

Slits A number of slits with varying slit number, width, and spacing are provided. It may be necessary to use a mask on the opposite side of the component carrier to insure that light is incident on only one pattern at a time.

Apertures and diffraction patterns Two circular apertures with different diameters and two special diffraction patterns are provided. It may be necessary to use a mask on the opposite side of the component carrier to insure that light is incident on only one pattern at a time.

Opaque points and Fresnel zone plates Circular opaque points and two Fresnel zone plates are provided. The two zone plates are complementary; the opaque zone of one is the transparent zone of the other. It may be necessary to use a mask on the opposite side of the component carrier to insure that light is incident on only one pattern at a time.

Diffraction grating A transmission type diffraction grating with 5276 lines/cm is provided.

Glass plate A 6 mm thick glass plate is provided.

Acrylic plate A 19 mm thick acrylic plate is provided. Acrylic plate is softer than glass and is scratched more easily.

Prism A $90°$–$45°$–$45°$ glass prism is provided.

Curved mirror An aluminum concave spherical mirror (50 mm radius of curvature, 25 mm focal length) is provided.

Viewing screen A viewing screen with a metric scale is provided for measurements.

Aperture mask The aperture mask is used to block unwanted patterns on multiple pattern components such as slits and diffraction patterns.

Light source apertures Circular apertures are provided to be used in front of light sources.

Glass tank The water tank is 90 mm in diameter and 50 mm in depth.

Hologram A transmission type hologram is provided.