

OPERATING INSTRUCTIONS

Speed of Light Lab No. 31911

1. Introduction

This equipment is used for the measurement of the velocity of light, according to the Foucault-Michelson method.

2. Description

The apparatus consists of the basic equipment necessary to measure the velocity of light using the method originally devised by Jean Foucault and later refined by Albert Michelson. You will need to supply some accessories, many of which are commonly available in the physics laboratory. These accessories are described in detail in section 3, "Setup."

The 31911 Speed of Light Lab consists of a rotary mirror, powered by an electric motor (Fig. 1). The motor is connected to a transformer, which enables it to be run off line voltage, and a rheostat, which lets you regulate the speed of the motor.

Fig. 1

The motor of the rotary mirror is housed in a casing about 185mm long and 55mm in diameter. The axle of the motor protrudes on top, where it turns the mirror. The mirror, 10mm x 20mm, is coated with an aluminum and quartz layer on either side. The cap of the unit is provided with an adapter piece with a 12mm hole for mounting the apparatus on stands.

You can adjust the mirror in the desired direction by using the key supplied with the unit. The key is attached to the case with a chain, and can be mounted on the mirror through a hole in the top of the cap.

CAUTION: When handling the rotary mirror, be careful to protect the mirror surface from mechanical damage and from fingerprints. Do not operate the motor with the adjuster key inserted.

The switch is at the bottom of the casing. The motor is permanently fitted with a two-core connecting cable that is approximately 7m long and ends in safety plugs.

The motor can reach a maximum speed of about 28,000 rpm. It is provided with a lubricant that will last for the life of the motor, so that relubrication should not be necessary.

3. Setup and Operation

NOTE: To make sure you obtain good experimental results, please read through the instructions on setup and operation BEFORE performing the experiment. Specific accessories and adjustments are necessary.

You can perform the following experiment in one of two ways. Your selection of method may depend on the space limitations of your lab.

In the first method, a straight light path about 15 meters long is required (see Fig. 2). If space does not permit this long a setup, a reflecting mirror can be used ("U" in Fig. 2), which will reduce the overall length of the setup to 7.5 meters and will also make it easier to adjust the apparatus.

Fig. 2

You will need the equipment listed below to perform the experiment. We have listed Central Scientific Company names and catalog numbers of the accessories, in case you need to order them, and for clarity we will refer to the accessories by our names and catalog numbers in this section.

However, we have tried to give an adequate description of all the products so that, if you have equivalent items on hand, you may use them. Some of the accessories are general items, such as stands and rods, which are commonly found in physics laboratories, and these are listed under the heading of "General Accessories." Other accessories are fairly specific, such as the 7.5cm double convex lens with 10cm focal length, and these are listed under the heading of "Unique Accessories." Additional accessories must be used if you choose the compact setup with reflecting mirror.

Please note that the accessories recommended are for performing the experiment on ordinary lab benches.

| Unique Accessories | | |
|--|---|-----------------------|
| How Many Needed | Descriptive Name | Catalog Number |
| 1 | Concert Pitch Tuning Fork, 440 Hz | 84562-08 |
| 1 | Universal Light Source with 100-watt projection lamp | 85264 |
| 1 | Precision Adjustable Rotatable Vertical Slit (max. length and width, 22mm and 2.5mm) | 46014 |
| 1 | Double Convex Lens, 3.75cm diameter, 10cm focal length | 85645-02 |
| 1 | Mounted Plano-Convex Lens, 12cm diameter, 5m focal length | 46012 |
| 1 | Engraved Glass Rule, with 50mm scale graduated in mm | 30118 |
| 2 | Plate and Grating Holder for objects up to 10mm square | 87050 |
| 1 | Front-Silvered Mirror, 12cm diameter, radius of curvature > 1 kilometer | 46320 |
| 4 | Saddle Base, for rods up to 16mm diameter | 72003 |
| General Accessories | | |
| 2 | Aluminum Rod with Shoulder, 1 x 30cm, threaded 1/4-20 | 72165-02 |
| 1 | A-Shaped Support Base with Leveling Screws, size 22 x 20cm, threaded 3/8-16 | 72002-03 |
| 2 | A-Shaped Support Base, 22 x 20cm, threaded 3/8-16 | 72002-02 |
| 3 | Aluminum Rod, 1.3 x 61cm, threaded 3/8-16 | 72175-03 |
| 2 | Parallel Aluminum Alloy Clamp for 13mm diameter rods | 12242-01 |
| 1 | Lens and Mirror Clamp, for lenses 20-100mm diameter | 72288 |
| 1 | Microscope Slide, 75 x 25mm, packed 72 per box | 66300 |
| 1 | Mounted Iris Diaphragm, opening adjustable from 1.5-30mm diameter | 46026 |
| If The Compact (7.5m) Arrangement is Used, Add These Accessories: | | |
| 1 | Front-Silvered Mirror, as described above | 46320 |
| 1 | A-Shaped Support Base, as described above | 72002-02 |
| 1 | Aluminum Rod, 1.3 x 61cm, as described above | 2175-03 |
| 1 | Parallel Aluminum Alloy Clamp, as described above | 12242-01 |

a.) The plano-convex lens and front-silvered mirror should be mounted to a 72002-02 A-base using a 72175 series stand rod and parallel clamp. The rotary mirror should be mounted on a 72002-03 A-base using a 72175-03 stand rod.

The 30118 glass rule and the clear glass microscope slide can be mounted in the 87050 plate and grating holder, which then can be attached to a 72165-02 stand rod in a 72003 base. Screw the threaded end of the rod into the plate and grating holder and insert the unthreaded end of the rod into the 72003 Saddle Base, securing it with the set screw.

The 85645-02 double convex lens can be held by the 72288 lens holder in a 72003 base. The 46014 Precision Adjustable Rotatable Vertical Slit can be supported in a 72003 base.

b1.) If you are using the setup without the reflecting mirror, you should arrange the apparatus on three benches in the following manner (refer to Fig. 2 for an illustration):

Bench 1: Universal Light Source and vertical slit. The lamp filament should be arranged in a vertical position and imaged on a wall nearly 5 meters away by means of the focusing lens. Directly behind the lens, provide a stand for attaching the slit later on. The lens ($f =$ approximately 5m) should be set up to the side of this stand.

Bench 2: Rotary Mirror. The mirror should be placed about 5 meters away from the stand for the slit on Bench 1.

Bench 3: Front-Surfaced Mirror as Distant Mirror. Place this mirror about 10 meters away from the projecting lens.

b2.) If you are using the compact (7.5m) arrangement with the reflecting mirror, you should set the apparatus up as follows (refer to Fig. 2 for an illustration):

Bench 1: Universal Light Source and vertical slit. The lamp filament should be arranged in a vertical position and imaged on a wall nearly 5 meters away by means of the focusing lens.

Directly behind the lens, provide a stand for attaching the slit later on. The lens ($f =$ approximately 5m) should be set up to the side of this stand.

Bench 2: Rotary Mirror and Distant Mirror. The rotary mirror (D) should be set up about 5 meters away from the stand for the slit on Bench 1. The distant mirror (E2) should be set up beside the rotary mirror.

Bench 3: Reflecting Mirror. Place this mirror about 2.5 meters away from the projecting lens.

c.) Your first step in adjusting the optical system will be to set the distance of the rotary mirror from the projecting lens by an autocollimation arrangement. Note: All adjustment steps are to be made with the rotary mirror motor off. Directions for energizing the motor will be given later in these instructions.

Turn on the Universal Light Source and use it to illuminate the rotary mirror (D). Using the key, turn the rotary mirror so that the reflected light falls on the center of the projecting lens (L), which you have set up about 5 meters away.

Put the front-surfaced mirror a short distance behind the projecting lens (L), so that the light beam reflected from the front-surfaced mirror forms an image of the rotary mirror alongside the rotary mirror itself. Find the location of the sharp image (by holding a pin in front of the rotary mirror), and vary the distance between the rotary mirror and the lens (L), until the image and the rotary mirror are at equal distances from the lens.

When you have completed this process, you will have established the correct positions for the rotary mirror and the lens.

d1.) If you are using the arrangement without the reflecting mirror, this is your next step.

Now you must adjust the distant mirror (E1 in Fig. 2). At the selected distance $r = f$, the mirror must be two focal lengths away from the lens (L). To check the corrected distance, you will have to reinsert the slit briefly. When the light from the rotary mirror falls on the center of the projecting lens, a sharp image of the slit must appear on the center of the distant mirror. To check this, hold a pin in front of the slit. You may have to adjust the position of the distant mirror.

When you have a sharp image on the distant mirror, adjust the leveling screws of the stand base to bring the plane of the mirror into a position in which the reflected light also passes through the center of the lens. You can make this adjustment more easily if you hold a sheet of white paper horizontally in front of the lens to indicate its midpoint.

d2.) If you are using the setup with the reflecting mirror, this is your next step.

See the arrangement shown by dashed lines in Fig. 2. You must set up the reflecting mirror (U) 2.5 meters behind the lens. You must set up the distant mirror (E2) alongside the rotary mirror (D), so that the beam of light bypasses the projecting lens on its way to the distant mirror. In this setup, the light must fall on the center of the projecting lens, then on the center of the reflecting mirror (U), and then on the center of the distant mirror (E2).

To check the adjustment of the setup, reinsert the vertical slit, which must form a sharp image on the distant mirror. You can check how sharp the image is by holding a pin in front of the slit; definition of the image can be improved by moving the reflecting mirror.

The adjustment of the return path of the light (where the image of the rotary mirror must be located on the rotary mirror) should be easier to make, because the rotary mirror and distant mirror are closer to each other.

e.) Now check the position of the distant mirror on the rotary mirror, making fine adjustments if necessary. The image of the rotary mirror must be received on the rotary mirror itself. This image can be found by inserting a piece of paper in the beam of light directly in front of the rotary mirror. If necessary, make slight horizontal and vertical adjustments of the distant mirror so that the image of the rotary mirror falls exactly on the mirror.

f.) The next step is to set up the glass rule and the eyepiece. When performing this step, be careful not to change the position of the stand bases or any of the other parts of the setup.

Insert the vertical slit and arrange a clean glass slide about 10 to 15cm in front of it, inclined at an angle of about 45 degrees. Put the glass rule in the beam of light reflected by the inclined glass slide. You must place the rule where the image of the slit is most well defined. Therefore, when the

rule is correctly positioned, it should be as far from the glass slide as the slide is from the slit. The image of the slit (approximately 0.5mm wide) will be seen doubled. It should be examined through a second lens ($f = 10\text{cm}$) used as an eyepiece.

Fig. 3

An iris diaphragm at the position of the aperture (image of the rotary mirror, about 100mm behind the eyepiece) will make it easier to bring the eye into the right position for observation, and shield against undesirable scattered light. Position the glass rule so the center of the double image reflected at the object slide coincides with a graduation mark.

g.) The last step is to connect the rotating mirror to the Speed of Light Control Unit (see Fig. 3). Before doing so, make sure the key on the mirror has been taken off. Plug the two safety plug terminals from the rotating mirror into the two "motor" sockets on the control unit. Polarity is not important, so either plug can be inserted in either socket. Before plugging the control unit in to the transformer, make sure the on/off switch is in the "off" position and that the fast/slow control is in the "slow" position.

Plug the control unit into the transformer socket and the transformer into a standard 110VAC outlet. To energize the rotating mirror, switch the control unit to "on" and then switch on the rotating mirror. At this rotating frequency the slit image in the ocular must be in the same position as before, although it might be of lower intensity.

h.) You can set the correct speed of the motor with an acoustic method, by comparing the noise of the motor with the sound of a 440 Hz tuning fork and adjusting the motor speed for zero beats. The speed of the rotating mirror can be adjusted by selecting "fast" on the fast/slow control switch and moving the slider on top of the control unit in the "fast" or "slow" direction. To move the slider, push down on the trailing edge and move the slider to the desired position.

Once the motor frequency and tuning fork frequency match, the deflection (S) should be measured. It is also necessary to measure the focal length f , since the lens may not have a focal length of exactly 5m.

The velocity of light can then be computed from the formula:

$$c = F(24 f_2 n \pi, s) \text{ m/s}$$

$n = \text{r.p.s.}$

4. Maintenance

The Speed of Light Lab requires no special maintenance. As noted before, avoid getting fingerprints on the rotating mirror or touching it with any object that might scratch it. A protective plastic cap is provided to cover the mirror assembly when it is not in use. When you are not using the Speed of Light Lab, keep the mirror covered and the unit unplugged.

If any difficulty develops with this apparatus, contact Central Scientific Company, giving details of the problem. So that we can serve you better, please do not return any apparatus until we have sent you a written authorization.