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The Magnetic Michelson Interferometer.

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Figure 1: The completed assembly



1 Introduction

This Educational Michelson Interferometer communicates the design principles of the LIGO Observatory and provides a simple demonstration of the wave nature of light. It is also of historical significance as a derivation of the instrument was used by Michelson and Morley in their search for the nonexistent "luminiferous aether". There are many ways to build a simple interferometer; this document is intended as a recipe for a basic design inspired by the design in "Build Your Own Michelson Interferometer"¹. The primary difference between these two designs is that the Magnetic Michelson's use of steel plate and magnets allow it to be taken apart and re-assembled on a regular basis by new sets of students, whereas Build Your Own describes a permanent setup. The Magnetic Michelson design can be constructed from scratch for under \$200.

¹(LIGO, http://www.ligo-wa.caltech.edu/teachers_corner/lessons/interferometer_9t12.pdf accessed June 11th, 2009)

2 Design and Construction

2.1 Safety Considerations

Use a laser pointer that is Class 2M or below (using the previous classification system, Class IIIa). Most generic pen-like red laser pointer should fall in this category. Avoid eye contact with the laser beam when building or using the interferometer. Super Glue can bond skin and should be used with care, be sure read the instructions and warnings.

2.2 Materials

The parts listed are just suggestions, many parts, such as magnets may be available at your local hardware or electronics store while others likely need to be ordered from company's such as Edmond Optics, Thorlabs or OptoSigma. It may be possible to order all the needed optics and mounts from a single manufacturer. The parts listed below are merely the configuration we found to be the optimal combination of price and suitability. Having one adjustable mirror mount is key. You must be able to make fine adjustments to one of the interferometer arms to insure the reflected beams can be brought together on the beam splitter.

Parts List

steel plate 12"x12x1/8".

ceramic magnets 15; three 5 pack, Radioshack, Model: 64-1888 \$9.

Rare Earth Magnets 4; two 2 packs, Radioshack, Model: 64-1895, \$4.

metal binder clips medium, 1 1/4"x5/8".

mirrors 2, Edmond Optics 25mm dia. NT32-945 \$28; Or Thorlabs, ME1-G01 - 25.4 mm Dia. \$24.

beam splitter Edmond AR coated. 20x37mm 50R/50T, NT31-413, \$30.

red laser pointer \$10.

mirror mount OptoSigma Small Mirror Mount, 12-0250, \$46. Or Thorlabs KMS, Kinematic Mirror Mount, Compact (Imperial) \$33, needs some additional hardware.

Figure 2: Permanent magnets glued to the base of an OptiSigma Mirror mount



beam expander lens Thorlabs LC1975 Plano-Concave Lens, 6 mm, $f = -24.0$ mm. \$13.60.

2.3 First Time Assembly

Some additional assembly is required the first time you build the Magnetic Michelson. **Super Glue**, or equivalent, is required, we also used a **rubber grommet** to mount our beam expander lens. Depending on your mirror mount, you may need to bolt on an additional plate to allow a sufficient area provide a sufficient surface for the 4 rare earth magnets which hold the mount to the steel plate. See **Figure 2** for what the magnets look like Super Glued to the OptiSigma mount. You can attach the mirror to the OptiSigma mount with a piece of **double stick tape**. Do not glue the ceramic magnets to the binder clips, the steel binder clips will be held securely by the magnets and this will make disassembly easier.

2.4 Complete Assembly

Once the gluing is completed you will have the parts for a readily re-assembled Interferometer. It is advisable that each group of students complete their own assembly at least once. After completing the initial assembly, use binder clips to hold the remaining optics (Beam Splitter, non-adjustable mirror and beam expander) as well as the laser pointer. Attach each item to the steel plate with circular magnets. You will probably need to stack several magnets to get the laser on the plane of the mirrors.

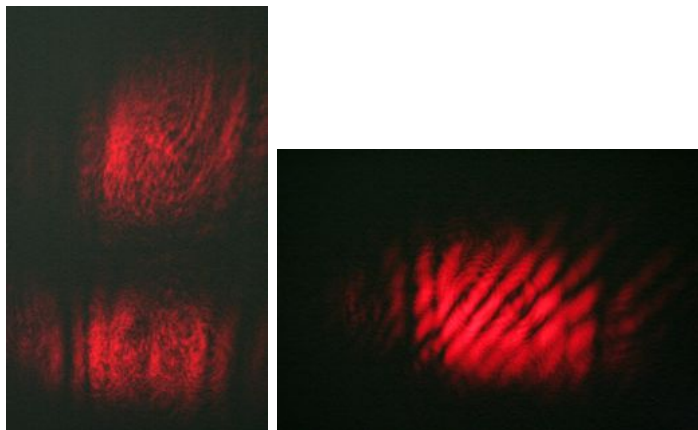
Figure 3: Binder clip with padded Beam Splitter and circular ceramic magnets, the same approach as the non-stage mirror mount



Figure 4: Beam expander lens mounted in rubber grommet



Figure 5: Photos of the output beam projected on a wall. On the left are two misaligned beams. Fringes due to optical imperfections are visible on the beam spots but are not sensitive to changes in the alignment of the optics. The picture on the right shows the beams overlapping and highly sensitive fringes, traveling across the beams at an (arbitrary) 45 degree angle.



3 Use and Interpretation

3.1 What are you looking for?

To observe an interference pattern it is important that the two reflected beams occupy the same space, that is, they need to overlap on the beam splitter. With the laser on, start by aligning the non-adjustable mount so that its beam hits near the middle of the beam splitter and position the beam expander so that this beam, after it reflects off the splitter, passes through it and can be projected onto a wall or paper. Next move the adjustable mirror so the beams overlap. Depending on the degree of misalignment you can look for the two beams on the wall, on the beam splitter or by moving a paper around near the beam expander.

Once you see the beam spots overlap you should see fringes, dramatic lines of light and dark. Depending on your alignment they are likely to look relatively straight. A perfectly aligned Michelson will show circular interference patterns. An example of such lines is shown in **Figure 5** The more lines there are the more of an angle between the two mirrors. To decrease the number of lines and increase the interferometer's sensitivity, you may need try displacing the mirrors (from side to side) and then re-adjust the angle of the adjustable mirror.

3.2 Ideas to explore

The interferometer is very sensitive to disturbances. Some things you can explore include:

- Vibrations from the ground, such as having someone jump near the interferometer and then trying to damp the motion with different materials.
- Changes in the air between the arms, such as breathing down one arm or heating the air.
- Applying heat one part of the platform so relative arm length slowly changes.

3.3 Additional Resources

Optics, Eugene Hecht, 4th Edition, Addison Wesley, 2002, page 407. Provides a mathematical derivation of the circular fringes obtained when the interferometer is precisely aligned.

Hyperphysics provides a basic overview of light behavior and includes schematics of the Michelson interferometer, photos of fringes and details of the Michelson-Morley experiment. <http://hyperphysics.phy-astr.gsu.edu/hbase/HFrame.html>.

Figure 6: Layout of a Michelson Interferometer

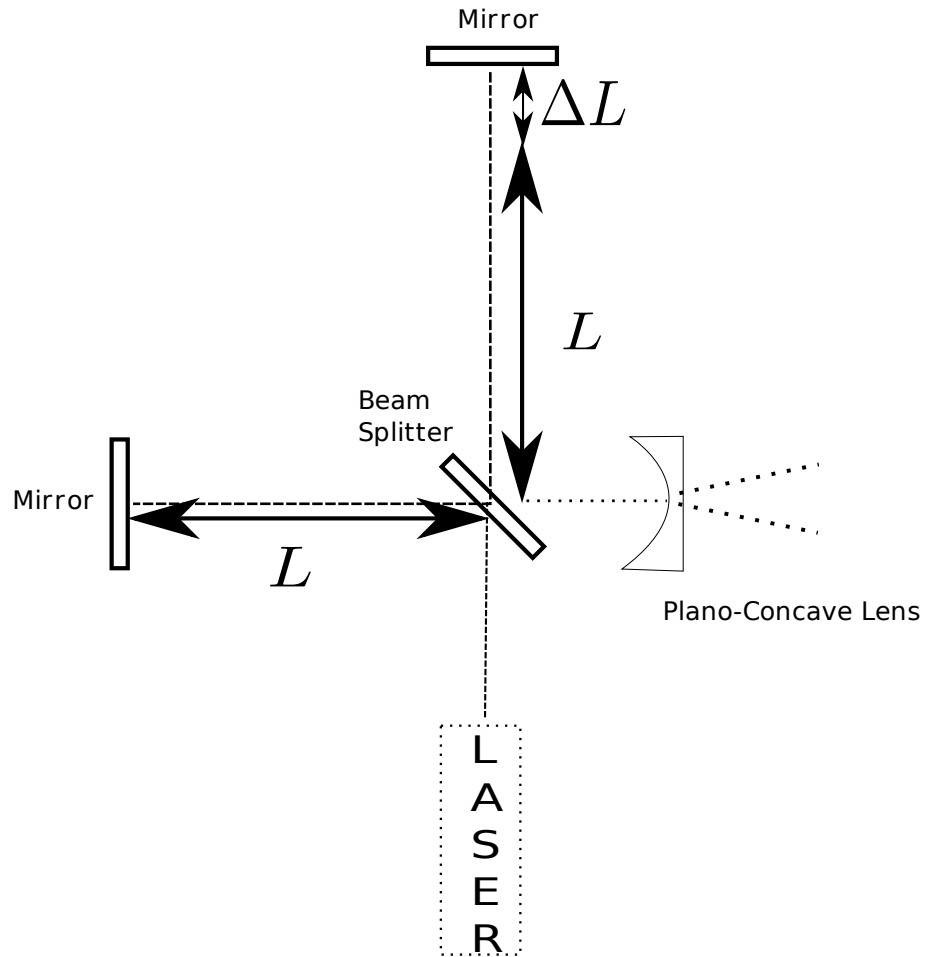


Figure 7: Top View



4 Appendix A- Student Handout*

Name:

If you have not done so already, spend some time observing the behavior of the interferometer (please don't touch the optical components). Gently turn the adjustment screw on the adjustable mirror and watch what happens to the interference pattern. With the interferometer completely focused, loop a string around the stand that supports the fixed mirror and gently pull on the loop. There are a variety of other experiments to do with the instrument, such as placing a sample of very hot water near one of the beam paths, halfway between the beam splitter and the end mirror. Those who built the device will just ask that you BE CAREFUL! Use your observations and outside resources (such as a physics book) to help you answer these questions. Feel free to draw pictures to clarify your explanation.

1. What do we mean by 'light interference'?
2. Can other types of wave that can undergo interference? If yes, please provide examples.
3. Describe the two types of wave interference.
4. Use the concept of interference to explain how the interferometer works.
6. Why is the instrument so sensitive to the position of the mirror?
7. Interferometers can be used to measure movements that are much, much smaller that you would measure with tools such as rulers. Using your experience of pulling on the mirror, explain how this is possible.
8. Do some quick research (perhaps on the Internet) and see if you can find some ways that interferometers are used in the 'real world'.

***Taken from "Build Your Own Michelson Interferometer"**