Building a Mach Zehnder Interferometer with Limited Resources

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Abstract

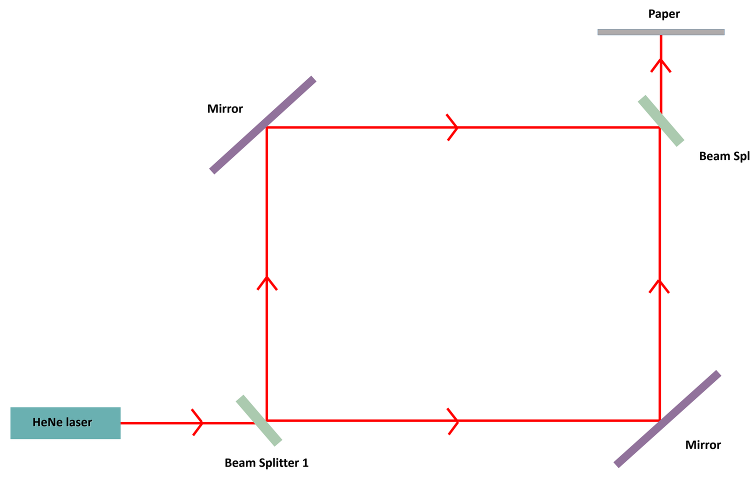
Interferometers are simple optical devices that function by splitting a coherent light beam. The beam is recombined using beam splitters and mirrors. The addition of the two light beams produces interference patterns in the forms of fringes which can be used to study the path taken by the two beams. This is old technology and we sought to construct an interferometer using rudimentary and cast-off equipment. The purpose is to show that modern physics concepts can be measured inexpensively and by undergraduate student design. Though we had no optics table and or optical mounts, by careful alignment and adjustments to the equipment, we were able to produce fringes whose intensity could measure phase changes of a light beam as it goes through various mediums. We were able to determine and learn more about the properties of light and produce successful results. This demonstrates a method of introducing modern physics lab applications at a low cost.

Background

Interferometers are used for many different applications in larger and more precise experiments. Different measurements can be taken using different configurations of the mirrors and beam splitters. Examples:

- Michelson
  - Used by LIGO to measure gravitational waves
  - Used by GONG to measure shifts in the spectra of airflow
- Twyman-Green
  - Used to measure small optical components for other purposes

Interferometers are extremely variable and versatile so building an understanding of how they work is incredibly important to future scientists.



A schematic of basic Mach Zehnder Interferometer(Left) and a commercial Mach Zehnder Interferometer (top)

Experimental Setup

Mach Zehnder Interferometers utilize:

- 2 beam splitters
- 2 mirrors
- HeNe laser
- 3 Lens
- Paper

In addition, we added an aperture of black construction paper to the source of the HeNe laser (image 3)

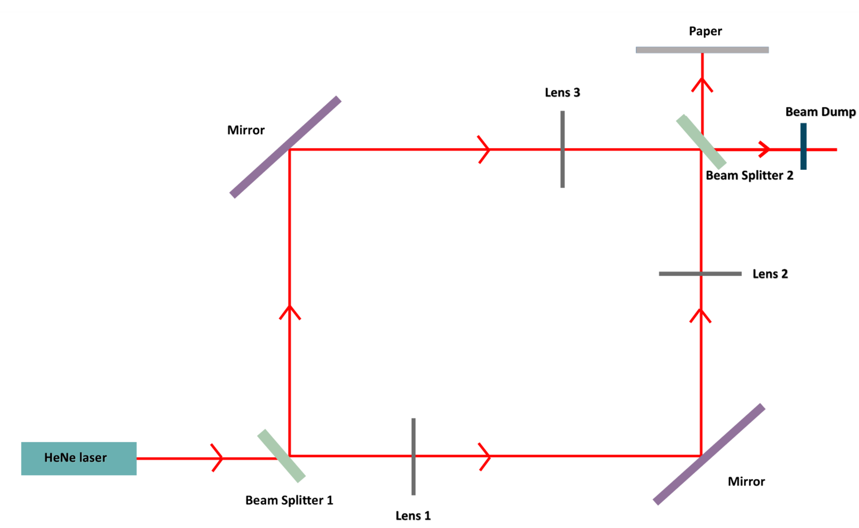


Image 1: diagram of our Mach Zehnder interferometer setup

Image 2: our Mach Zehnder interferometer setup in our lab

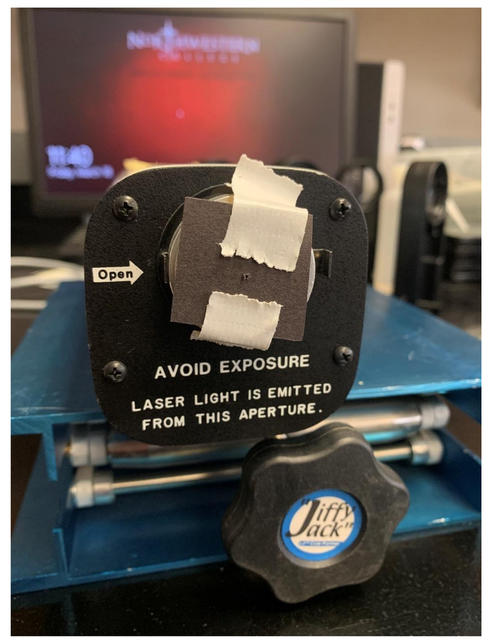
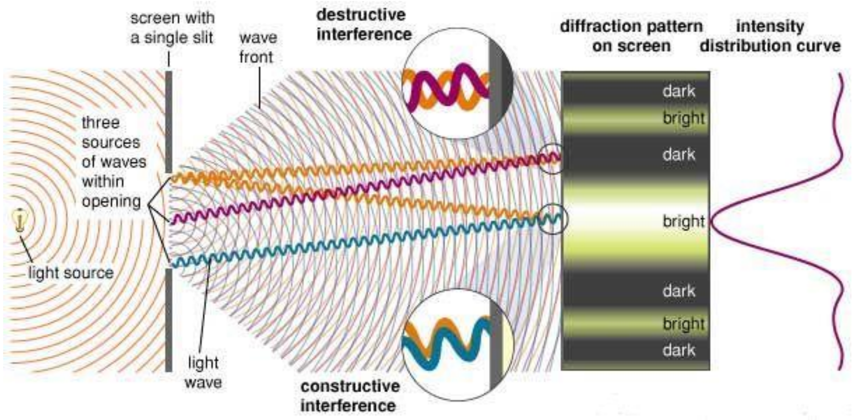


Image 3: aperture setup on HeNe laser

Phasor Addition

- Fringe patterns are created by the destructive and constructive interference of light recombining from different optical paths.
- Two waves with that align and overlap will create a larger amplitude and a brighter pattern on the screen
- Two waves that have align oppositely will cancel out and create a dark pattern on the screen



Results

Results exhibit pictures of fringes we acquired with our limited setup. We observed and captured a picture of the the fringe patterns on black construction paper. Image 1 depicts the fringe patterns on paper of the light beam through no medium on paper. Image 2 shows the same fringe patterns, but from an opposite view looking at the laser. Then, we were able to manipulate the fringe patterns by placing different mediums in the light's path. As shown in image 3, we did this by placing a plastic lens in the path of the mirror. This is one way to test a variety of optical materials such as lens. When comparing the two images, the fringe patterns have shifted depending on the mediums.

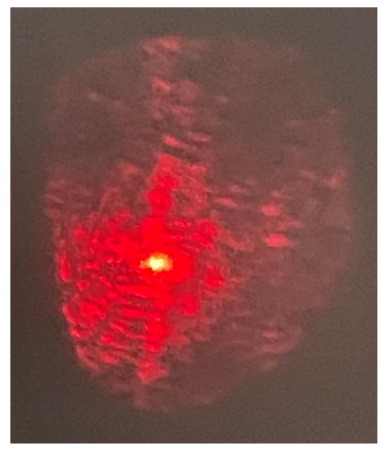


Image 1: fringe pattern with no medium on paper

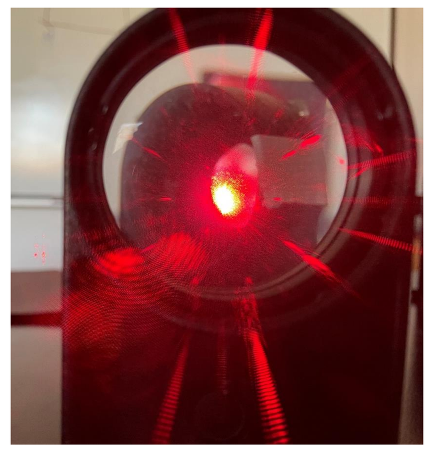


Image 2: fringe pattern with no medium looking at laser

Image 3: shifted fringe lines through plastic lens on paper

Adjustments

The equipment available to us was limited and exhibited faults, so we had to make a variety of adjustments to get desired results.

1. To fix the problem of a dirty laser beam, we created an aperture of black construction paper to create a cleaner beam.
2. The beam splitters we used contained flaws and aberrations which resulted in one of the split beams to have four beams instead of one. By tweaking the alignment, we were able to get a somewhat cleaner beam and ended up following the strongest one.
3. Due to lack of optical table, we attached the beam splitters and mirrors to lens holders to make sure they were level and even.

Sources

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Acknowledgements

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