Michelson Interferometer

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Abstract
The Michelson Interferometer is an optical tool used in optical interferometry, which is the technique of superimposing electromagnetic waves such that they form interference patterns. This allows for the study of those waves. It is able to detect and measure changes in lengths down to the nanoscale because it is extremely sensitive to small changes. One example of the use of the Michelson Interferometer is the Laser Interferometer Gravitational-Wave Observatory, in short LIGO. It is on a much larger scale, consisting of 2 laser interferometers 3000 km apart. With the aid of a Michelson Interferometer, we measured the wavelength of the light from a laser from which we calculated its frequency and period too. Furthermore, we calculated the angle of magnification of the beam expander and also measured the light intensity of the lasers at varying locations.

Introduction
Many things in our daily lives such as the height of a table or the length of our feet can be easily measured with a metre ruler. However, when it comes to measuring tiny wavelengths of electromagnetic waves such as light, an optical instrument has to be used; the Michelson Interferometer. Light waves are too small to be seen with the naked eye and no type of ruler can be shrunk to such a small size and be controlled by people. A Michelson Interferometer makes use of mirrors to superimpose light waves which results in an observable interference pattern. From there the set-up can be tweaked to cause changes in the interference pattern and the wavelength of light can be calculated. The Michelson Interferometer is an effective solution as it is very accurate thanks to its sensitivity and the set-up and calculations are not too complicated. However, it has one con. Due to its sensitivity, small disturbances in the surroundings can affect the observed interference pattern and consequently the results of the experiments. For instance, small vibrations on the surface of the table will cause the mirrors to vibrate too and change the distance the light travels, affecting the results.

Solution Design
We used a Michelson Interferometer to measure the wavelength of light. A laser beam, which is expanded with the use of a beam expander, is shone towards a mirror coated with silver, called a beam splitter. The beam splitter splits the beam into 2 separate beams; 1 beam is reflected at a 45-degree angle to the left while the other beam passes straight through the beam splitter. Both beams then hit a mirror and are reflected back towards the beamsplitter. The two beams are combined by the beamsplitter and shone onto a screen where an interference pattern forms. We also drew a line above one of the dark fringes to mark out its position.

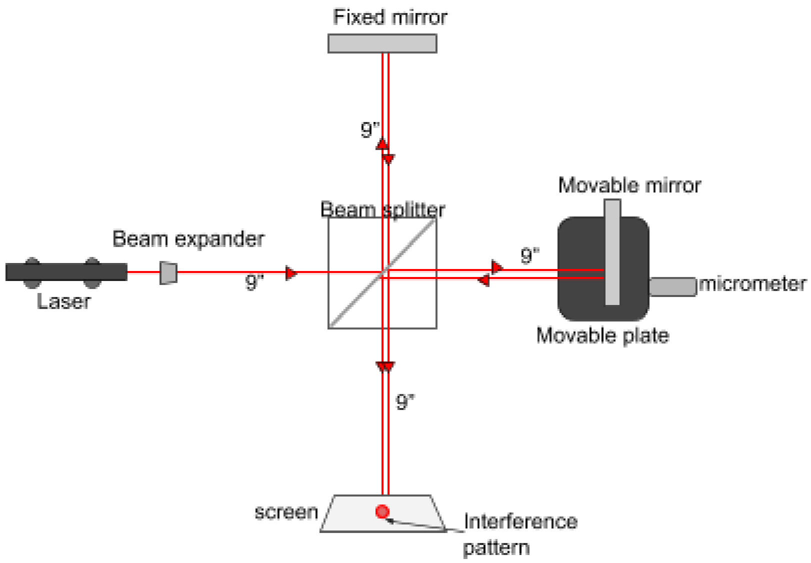
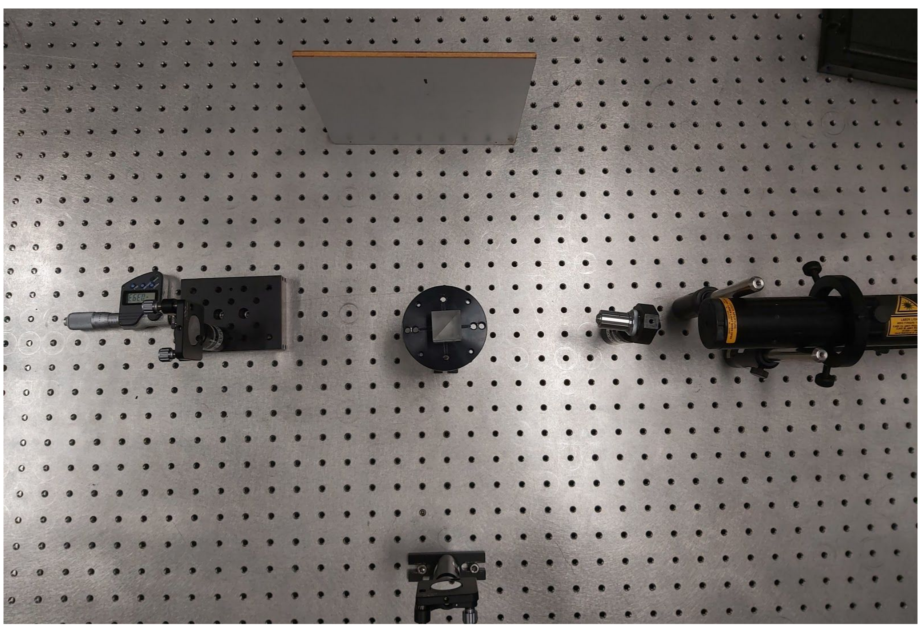
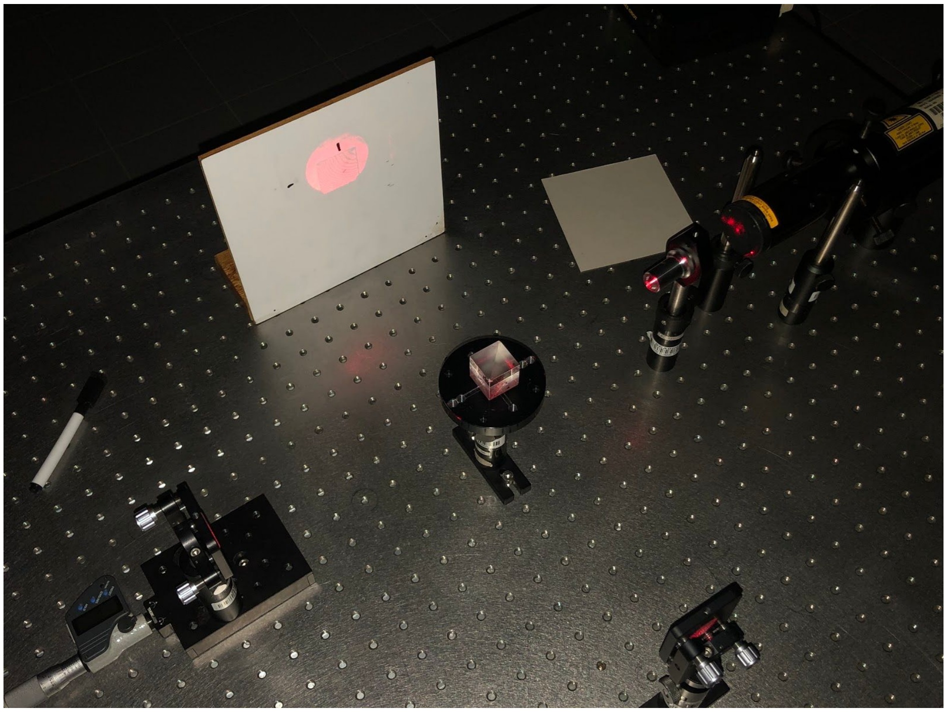


Diagram of set-up



Picture of actual set-up



Set-up when laser is turned on

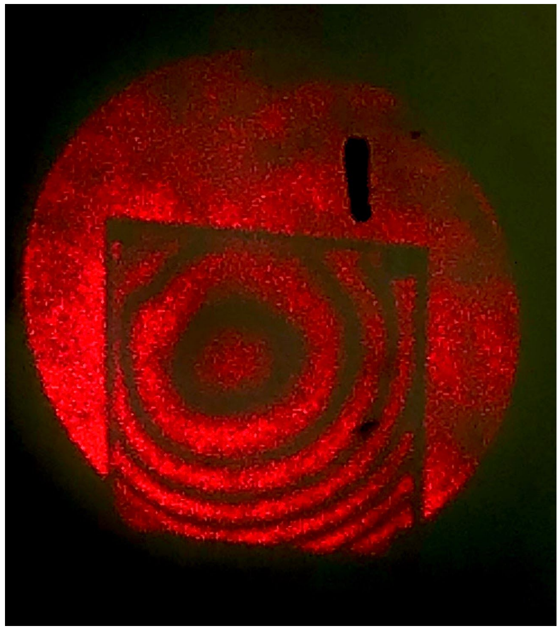


Image of interference pattern on the screen and mark above the interference pattern

Results and Discussion

Number of fringes, *m*	Distance moved by mirror/mm	Distance moved by mirror/nm	Wavelength/nm
25	0.008	8000	640
30	0.007	7000	466
27	0.008	8000	592
25	0.009	9000	720
27	0.009	9000	667
26	0.007	7000	538
25	0.007	7000	560
27	0.010	10000	741
25	0.009	9000	720
25	0.008	8000	640

The wavelength of light was calculated using the formula λ=2d/m, where λ is the wavelength of the light, *d* is the distance moved by the mirror and *m* is the number of fringes that passed the mark. This is because when the mirror moves by a distance that is equal to the 1/2λ, the total distance that the light travels from the beam splitter to the mirror and back is affected by 1λ. There will be constructive interference of waves and 1 fringe will pass the mark. Hence λ=2d. Since *d* is the distance moved by the mirror for more than 1 fringe, *m* to pass the mark, to find the distance for 1 fringe to pass, *d* has to be divided by *m.* Therefore λ=2d/m.

Experimental results show that on average, wavelength is 628 nm
Actual wavelength is 632.8 nm
Error = 0.695%

<u>Frequency of light wave</u>

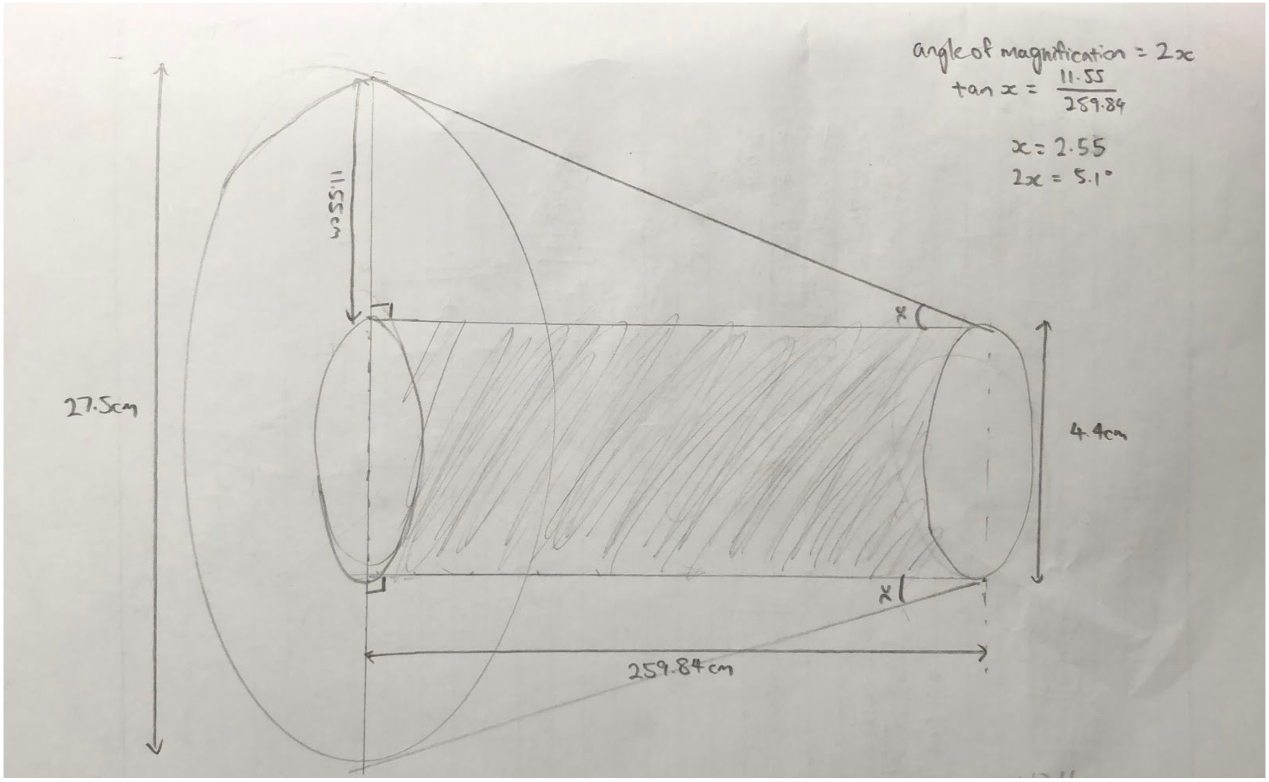
The frequency of light waves refers to the number of light waves that form in 1 second.
Velocity of light, *v*= wavelength of light, λ x frequency of light waves, *f*
3.00 x 108 ms-1 = 6.28×10^{-7} m x *f*
f = 4.78×10^{14} Hz

<u>Period of light wave</u>

The period of a light wave refers to the amount of time taken for 1 light wave to form.
Period of light wave, p = 1/Frequency of light wave, f
p = $1/(4.78 \times 10^{14})$ s
= 2.09×10^{-15} s

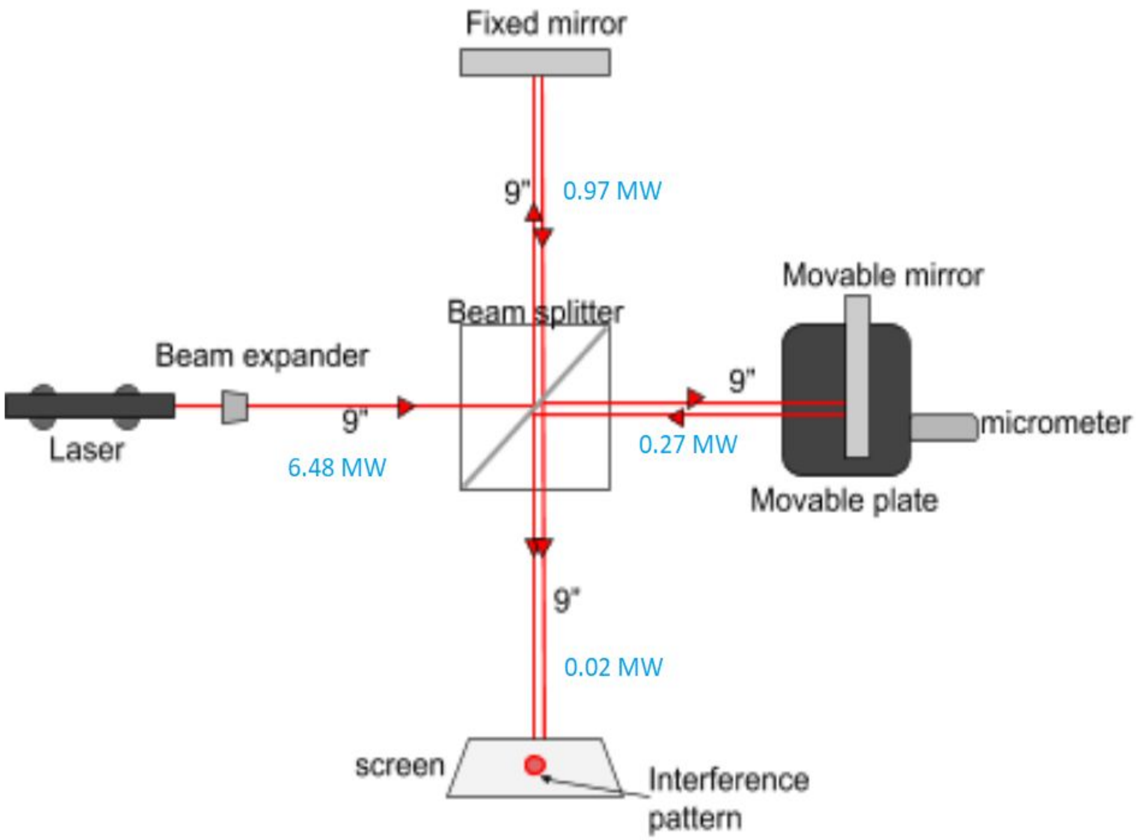
<u>Angle of Magnification of Beam Expander</u>

With the aid of an expander, we measured the diameters of the interference pattern at distances of **4 inches (10.16 cm)** and **270cm** from the beamsplitter, a difference of **259.84cm**.
Using tangent to find the angle of magnification, we derived a result of **5.1°**.



angle of magnification = 2x
tan x = 11.55 / 259.84
x = 2.55
2x = 5.1°
11.55cm
27.5cm
x
x
4.4cm
259.84cm

Light Intensity of Laser



The above results show the intensity of light at various locations. The intensity decreases as it travels a longer distance.

Conclusion

From numerous experiments, we derived the average wavelength of the laser to be 628 nm, with 0.7% error, and calculated the frequency and period to be 4.78 x 10^{14} Hz and 2.09x10^{-15} s respectively. Other experiments we conducted were using a photometer to measure light intensity at various locations and finding the angle of magnification of the beam expander, with a result of 5.1°.

Future Work Recommendations

We can test the effects of sound waves on the interference patterns on the screen. We can experiment using different musical instruments that produce different frequencies of sound waves.

Acknowledgements

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