MODULE 11

INTERFEROMETER

1. GOAL

1.1. Determine the value of ratio between movement of mirror and movement of micrometer screw gauge

2. EXPERIMENTAL APPARATUS

2.1 Precise interferometer set (1 set)
2.2 He-Ne laser (1 set)

3. BASIC THEORY

Interference is superposition phenomena of two waves that produce a pattern with periodically varying intensity as a result of constructive and destructive superposition. When observing light wave, the interference result will be observed as a pattern of alternating bright and dark lines. Interference pattern were set up to have same frequency and amplitude, as well as same phase. Interferometer is a configuration of lenses and a coherent light source (from LASER) to produce interference pattern. One of well-known interferometers is Michelson interferometer. Michelson initially developed the interferometer to examine the characteristics of light wave, especially to detect *Luminiferous aether* or ether. Ether, in the past, was believed to be a matter which responsible to propagate the light wave. Ether was also believed to be transparent and present throughout the universe.

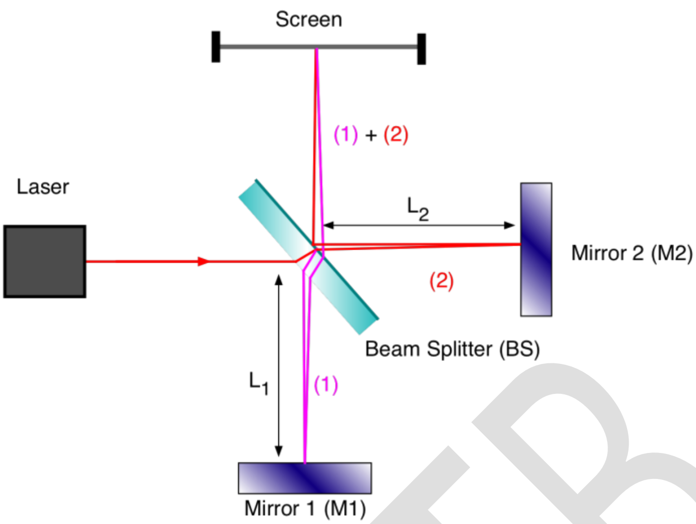

Figure 11.1. Michelson interferometer configuration.

Michelson interferometer consists of two flat mirrors and a beam splitter (BS), as in Figure 1. As seen in the figure, the interferometer splits a light beam into two equivalent light beams by using beam splitter (BS) and then recombine them into one on the screen. Half of the light were reflected to moveable mirror (M1) and half other were transmitted to adjustable mirror (M2). Both the beam 1 and beam 2 were reflected back to beam splitter and then continues to the screen. M2 mirror can be set by the micrometer as a tool to configure distance between M2 and the BS more accurately to scale of nm. On the screen, there are constructive and destructive superpositions in circular shape, known as Newton's ring. The resulting pattern depends on the phase difference of the beams when they come to the screen.

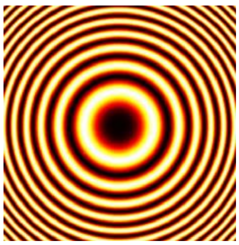

Figure 11.2. Michelson interferometer configuration.

The shifting ratio is introducing to describe the ratio between movement of mirror and movement of screw micrometer. The value depends on the characteristic of each instrument. This ratio could be calculated by the following formula:

$$k = \frac{n\lambda}{2\Delta x} \tag{11.1}$$

Information:

k	= the shifting ratio
n	= number of rotations
λ	= the wavelength of the laser (nm)
Δx	= distance difference on micrometer screw gauge (mm)

4. EXERCISES

4.1 Derive Eq. (11.1) and explain the required condition of constructive and destructive interference!

4.2 Explain what will happen if the light beam is not equivalently splitted (50:50)!

4.3 Explain why the observed interference pattern has a shape of bright and dark rings! Is the center supposed to be bright or dark spot?

5. EXPERIMENTAL METHODS

This experiment will be conducted as follows:

5.1 Configure the interferometer until bright and dark pattern is observed,

5.2 Specify the observed pattern and determine the lenses' shift,

5.3 Find the wavelength of laser.

5.1. Experiment Set-up (together with assistant)

1. Set up the components on the base plate and He-Ne laser on its stand as in Figure 11.3. Install the micrometer screw, which is useful for adjusting position of the mirror M2 precisely, on its place as in the figure,
2. Adjust He-Ne laser position so that the beam passes through divergent lens and is reflected by mirror M2 to divergent lens through its center,
3. Loosen the screw of divergent lens and rotate the lens by about 90° out of the line formed by the laser beam, so that the beam reaches the mirror M2.

Adjust beam splitter position (after loosening the screw) until beam 1 and 2 reach the same spot on the screen (completely overlapping). The interference pattern could not be seen yet because the beam spot is small,

4. Return the divergent lens back to its position so that the laser beam passes through it,
5. Adjust the lens finely until the interference pattern (bright and dark rings) clearly observed.

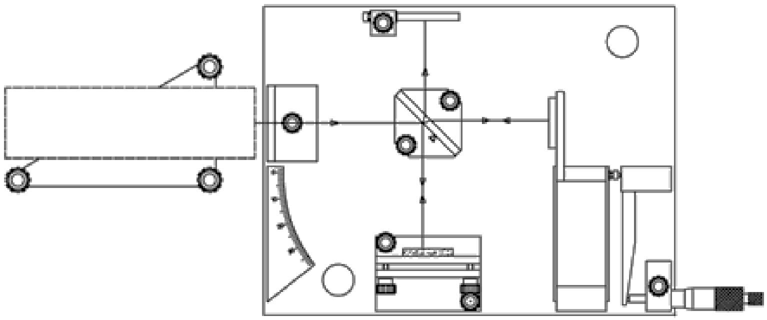

Figure 11.3. Michelson interferometer setup used in this experiment.

5.2. Lens' shift measurement

1. Set micrometer position at around 20 to 22 mm and adjust configuration finely so that the bright pattern in the center is perfectly formed. Write down the position of the adjusting micrometer screw (call it as x_i),
2. Change position of mirror M2 by turning the adjusting micrometer screw slowly in clockwise direction and continuously while observing how many times the pattern returns to its initial shape. Do it until the pattern repeats its shape 10 times ($n = 10$). Write down current position of the adjusting micrometer screw (call it as x_f),
3. The data can be collected in around its sensitive range of 5-10 mm and 11-20mm depending on each tool. Outside the range, the tool's sensitivity has been decreased.
4. To reduce error in counting rings and determining the position x_i and x_f, repeat the step 3 above 3 times for clockwise rotation and repeat 3 more times for counterclockwise rotation,
5. Take a look to the tool used, each set has its own wavelength reference and the shifting ratio reference. Then, calculate the shifting ratio of each data using equation (11.1),
6. Take the average of the shifting ratio for each set of variations,

7. Take the final average of the shifting ratio for clockwise rotation and the shifting ratio for counter-clockwise rotation and calculate the error.
8. Finally, take the average of the shifting ratio from CCW-rotation and CW-rotation and calculate the error.

6. ANALYSIS

6.1 Find shift ratio of the mirror by using equation (11.1)!
6.2 Compare the obtained shift ratio from experiment with reference!
6.3 According to no. 2, is there any differences? Explain the reason!
6.4 What is the physical meaning of shift ratio in this experiment?
6.5 Explain how to get a clear interference pattern!
6.6 Explain how the screw can change the interference pattern!

7. REFERENCES

Halliday, D., Resnick, R., Walker, J. (2006): *Fundamentals of Physics6th Edition*, John Wiley & Sons, 880 – 881.

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