BIRZEIT UNIVERSITY

Faculty of Science

Physics Department

Physics 212

Michelson Interferometer

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– Abstract:

The aim of this experiment is to determine the calibration constant and measure the index of refraction of glass. By using Michelson interferometer, mercury light and green filter have been used to find the calibration constant from the slope of graph Micrometer Scale vs Number of Fringes. Also by using it, a white light was used to measure the index of refraction of glass. The calibration constant was ($c \pm \Delta c = 0.1847 \pm 0.0007$) and the index of refraction of glass was ($n=1.642$).

– Theory:

Light from a source s is divided into two beams by a partially ref1ectig mirror. (A partially reflecting mirror is a piece of glass with a thin coating of aluminum on one side. Part of the incident light is transmitted and part is reflected). Each of these beams is reflected back by a fully silvered mirror (M1 and M2). Again, part of the returning light is transmitted and part is reflected by the partially reflecting mirror.

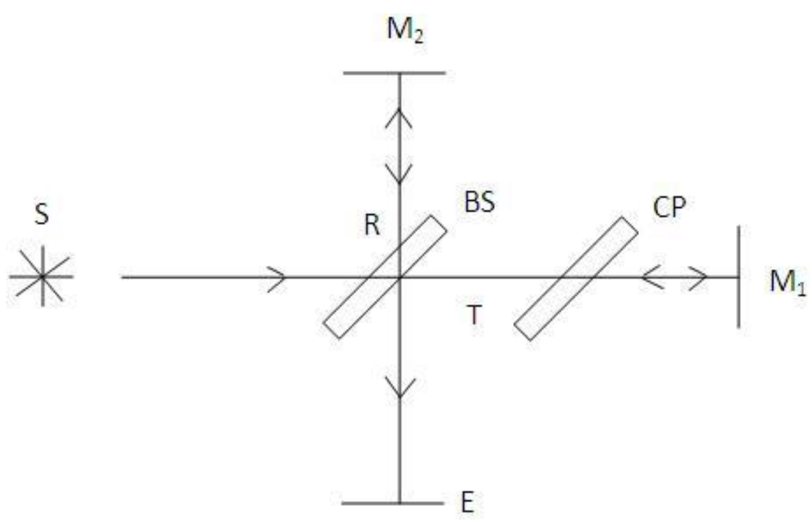


Fig. 1

The two beams of light reaching the eye of the observer have travelled different paths. The two rays are in phase when they are first separated at the partially reflecting mirror. If they travel different distances, a phase difference between the two waves will be introduced and interference will occur when the two rays are recombined by moving one of the mirrors forward or backward, the path difference 2d=2(L1-L2) and therefore the phase difference Δϕ may be varied.

The resulting interference pattern consists of circles. The condition for constructive interference is:

$$2d\cos\theta = m\lambda \quad , \quad m = 1,2,3,\ldots$$

From graph Micrometer Scale vs Number of Fringes:

$$X_m = slope \cdot f + y_{int}$$

X_m: micrometer displacement

f: $number\ of\ fringes$

$$x = c \cdot (X_m - y_{int})$$

x: actual mirror displacement

c: calibration constant

$$c = \frac{x}{(X_m - y_{int})}$$

For one fringe, the actual displacement = λ/2

$$c = \frac{\lambda/2}{X_m(1) - y_{int}} = \frac{\lambda}{2 \cdot slope}$$

$$\frac{\Delta c}{c} = \frac{\Delta slope}{slope} \to \Delta c = c \cdot \frac{\Delta slope}{slope}$$

Wavelength of green light which used = 5461Å

To measure the index of refraction of a material using the Michelson interferometer we first adjust the position of the movable mirror to give zero path difference between the two rays. (Assume that the movable mirror is M2 for this discussion). This can be done by adjusting the position of M2 to give white light fringes. Because the coherence length of a white light source is very short, we will only obtain white light fringes if $\Delta x=0$. We then place our sample of thickness T in the path to the fixed mirror. This increases the optical path length to M1 by $(n-1)T=\Delta D$. To return to the condition $\Delta\phi=0$, and recover the white light fringes, we must move M2 back a distance ΔD so that the optical path lengths for the two rays will again be equal.

$$D = c \cdot \left|X_a - X_g\right|$$

$X_a: micrometer\ scale\ in\ air$

$X_g: micrometer\ scale\ in\ glass$

$$T \cdot (n-1) = D$$

$$n = \frac{D}{T} + 1$$

$T: glass\ thickness$

$n: index\ of\ refraction\ of\ glass$

– Procedure:

Prepare the apparatus: mercury lamp, a green filter, Michelson interferometer kit, optical bench, micrometer scale.

1. Set up the interferometer: make the distance to M_1 and M_2 (from the partially reflecting mirror) equal. Turn on the mercury lamp and put a green filter. You should put a white glass plate in front of the light source; to diffuse the light.

2. Calibration of the mirror movement: Adjust the mirror position until only a few fringes are in the field of view. As the mirror M_2 moves in the direction which decrease the mirror spacing (d). Every time a fringe disappears into the center, the mirror position changes by δx. Count the disappearing fringes and note the micrometer reading every time 50 fringes have disappeared. Obtain the micrometer readings 7 times.

3. Measurement of refractive index: when you adjust the position of M_2 to be near the point of zero optical path difference, remove the green filter and switch to the white light. Turn the micrometer until fringes appear. Tilt the fixed mirror to obtain straight fringes. Turn the micrometer screw to center these fringes and note the micrometer reading. Then, place a thin glass plate in the path to M_1. Search for the white light fringes and record the reading of the micrometer. Don't forget to measure the thickness of the glass.

– Data:

PART I:

Number of Fringes	Micrometer Scale
0	10.000
50	10.075
100	10.150
150	10.225
200	10.295
250	10.370
300	10.445

PART II:

T: Glass Thickness (mm)	1.150
X_a: Micrometer scale in air (mm)	13.800
X_g: Micrometer scale in glass (mm)	17.800

– Calculations:

PART I:

	Slope	y-int
Value	0.001478571	10.00107143
Error	5.53283E-06	0.000997446

$$c = \frac{\lambda}{2 \cdot slope} = \frac{5461 \times 10^{-10}}{2 \times 0.001479} = 0.1847$$

$$\Delta c = c \cdot \frac{\Delta slope}{slope} = 0.1908 \times \frac{5.533 \times 10^{-6}}{0.001479} = 0.0007$$

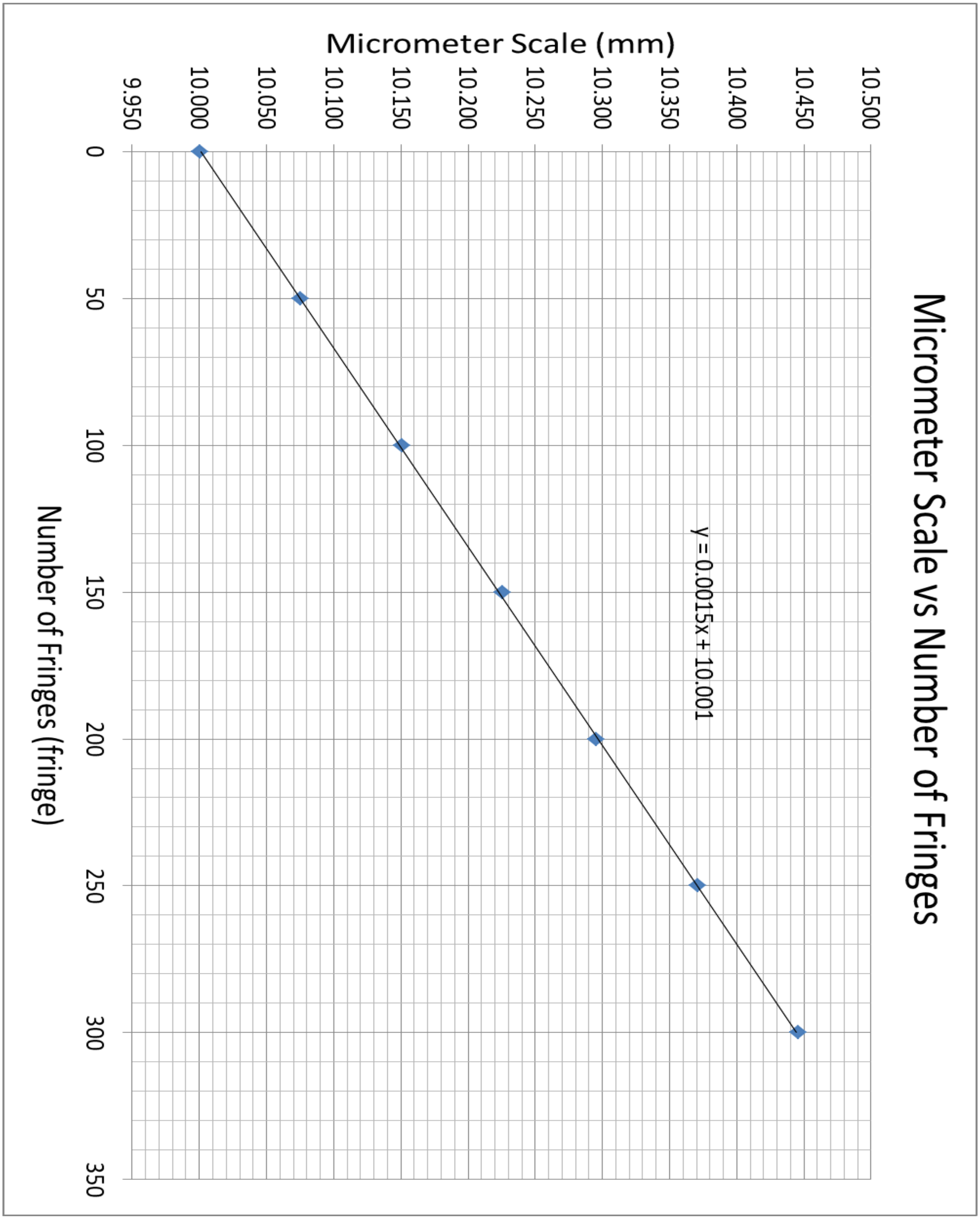
$$c \pm \Delta c = 0.1847 \pm 0.0007$$

PART II:

$$D = c \cdot \left| X_a - X_g \right| = 0.1847 \times |17.800 - 13.800| = 0.7387$$

$$n = \frac{D}{T} + 1 = \frac{0.7387}{1.150} + 1 = 1.642$$

$$n = 1.642$$


Micrometer Scale vs Number of Fringes
y = 0.0015x + 10.001
Micrometer Scale (mm)
9.950
10.000
10.050
10.100
10.150
10.200
10.250
10.300
10.350
10.400
10.450
10.500
0
50
100
150
200
250
300
350
Number of Fringes (fringe)

– Results:

$c \pm \Delta c = 0.1847 \pm 0.0007$

$n = 1.642$

– Discussion:

The calibration constant in this experiment was c±Δc=0.1847±0.0007. The real value is 0.2. Both values are close to each other but there are some systematic errors. For example, a small rotation in the micrometer makes a lot of constructive and destructive interference fringes appear and disappear in the middle of the screen. This lead to hardness in reading how many fringes have passed on the screen. Moreover, the experimenter may have lost in counting the number of fringes. Another reason came from the errors of approximation in micrometer.

The index of refraction of glass in this experiment was n=1.642. The real value is 1.5. Both values are close to each other but there are some systematic errors. For example, the fringe pattern without glass extends to a small rotation in micrometer. But when the glass slide was put, the fringe pattern extends to a large rotation in micrometer. Another error came from the dust on the glass.

– References:

1. Laboratory Manual, PHYS 212, Modern Physics Lab, Second Edition.
2. http://vlab.amrita.edu