# Optics

Interferometer

PHYSICS EXPERIMENT

# Michelson Interferometer II

## DETERMINE THE REFRACTIVE INDEX OF GLASS.

- **Determine the refractive index of glass.**
- **Determine the quality of the surface of a strip of adhesive tape.**

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## BASIC PRINCIPLES

**The Michelson interferometer can be used for interferometric measurements of various quantities, such as changes of distance, the thickness of layers, or refractive indices, because the observations are sensitive to very small changes in the optical path length of a partial beam. If the geometrical beam path is kept constant, it is possible to determine refractive indices and variations therein from changes in pressure, temperature, or density.**

Depending on whether the optical path length is shortened or increased, interference fringes are formed or disappear at the centre of the circular interference pattern. The relationship between the change $\Delta s$ in the optical path length, the light wavelength $\lambda$, and the number $m$ (positive or negative) of interference fringes that appear or disappear on the screen is described by the equation:

(1) $$2 \cdot \Delta s = m \cdot \lambda .$$

If a glass plate is placed obliquely in the path of one of the partial beams, the optical path length is changed by the amount $\Delta s(\alpha)$ given by Equation (2).

(2) $$\Delta s(\alpha) = \frac{d}{\cos\beta} \cdot (n - \cos(\alpha - \beta))$$

$d$: thickness of the glass plate, $n$: refractive index of the glass, $\alpha$: angle of incidence on the plate, $\beta$: angle of refraction into the plate.

According to Snell's law of refraction, $\alpha$ and $\beta$ are connected by the relationship:

(3) $$\sin\alpha = n \cdot \sin\beta$$

If the glass plate is first placed exactly perpendicular to the beam and is then turned from that position through the angle $\alpha$ the resulting change in the optical path length is:

(4) $$\Delta s = \Delta s(\alpha) - \Delta s(0) = \frac{d}{\cos\beta} \cdot (n - \cos(\alpha - \beta)) - d \cdot (n - 1)$$

By making a slight modification, the Michelson interferometer can be converted into a Twyman-Green interferometer, an instrument for measuring the surface quality of optical components. A Twyman-Green interferometer is normally understood to mean an instrument in which the (laser) light beam is expanded and formed into a parallel beam. However, for the qualitative understanding of the principle, a beam that is divergent rather than parallel can be used.

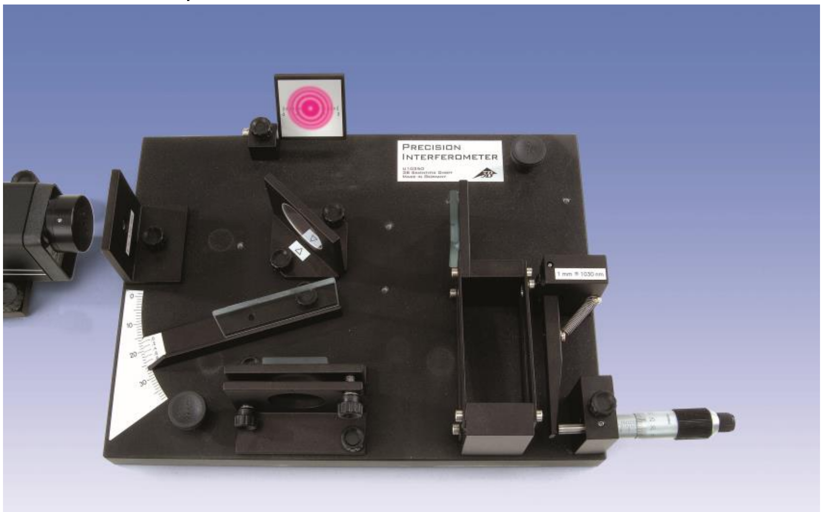


Fig.1: Experiment set-up for determining the refractive index of glass using a Michelson interferometer

# LIST OF APPARATUS

| | | |
|---|---|---|
| 1 | Interferometer | 1002651 (U10350) |
| 1 | Accessory Set for the Interferometer | 1002652 (U10351) |
| 1 | He-Ne Laser | 1003165 (U21840) |

# SET-UP

*Note*: The height of the light beam above the baseplate must be 60 – 62 mm.

- Place the interferometer on a stable and firm table with its base as accurately horizontal as possible.
- Mount the laser on the laser support using the hexagonal adjusting screw and position it facing as directly as possible into the beam-diverging lens.
- Remove the fixed mirror and the beam splitter.
- Loosen the knurled screw of the diverging lens and swing the lens out of the path of the beam.
- Adjust the position of the laser so that its beam falls on the centre of the moveable mirror and the reflected beam falls centrally on the laser.
- Swing the diverging lens back into the beam path and correct the beam path so that it also falls on the centre of the lens.
- Swing the diverging lens out of the path of the beam again.
- Mount the fixed mirror and, using the adjusting screws, set it so that the distance between the mirror mounting plate and the actual mirror support is about 5-6 mm and is uniform all around.
- Mount the beam splitter with its half-silvered side (marked with a triangle) towards the near left corner (between the laser and the fixed mirror), and adjust it so that the two brightest points that are visible on the observation screen lie as nearly as possible on a vertical line.
- Adjust the fixed mirror so that these two brightest points on the screen are made to coincide exactly.
- Swing the diverging lens back into the beam, adjust it so that the brightest part of the image is at the centre of the screen, and fix it in position with the screw.
- Tilt the screen slightly from the vertical position so that the observer sees a bright and clear image.
- Readjust the fixed mirror so as to obtain interference rings centred at the middle of the screen.

# EXPERIMENT PROCEDURE

**Determine the refractive index of glass:**

- Place the glass plate with the rotatable holder in the front partial beam.
- Make a slight adjustment to the moveable mirror so that the interference rings remain at the middle of the screen.
- Rotate the glass plate back and forth slightly about the 0° mark to determine the angle $\alpha_0$ at which new interference rings cease to form and they start to disappear instead.
- Readjust the beam splitter so that the angle $\alpha_0$ is as close as possible to the 0° mark.
- Starting from the angle $\alpha_0$, slowly rotate the glass plate and carefully count the number of rings that disappear, *m*.

**Application of Twyman-Green interferometer to evaluate the surface quality of a strip of adhesive tape:**

- Place the glass plate with the rotatable holder in the front partial beam in such a position that the beam also falls on the adhesive tape on the glass.
- Make a slight adjustment to the moveable mirror so that the interference rings remain at the middle of the screen.

# SAMPLE MEASUREMENTS AND EVALUATION

**Determine the refractive index of glass:**

Table 1: The number *m* of interference rings that disappear and the calculated change in path length.

| $\alpha$ | *m* | $m\lambda$ / µm |
|---|---|---|
| 0.0° | 0 | 0 |
| 5.0° | 20 | 13 |
| 7.8° | 40 | 25 |
| 9.2° | 60 | 38 |
| 10.9° | 80 | 51 |
| 12.0° | 100 | 63 |
| 13.6° | 120 | 76 |
| 14.6° | 140 | 89 |
| 15.8° | 160 | 101 |
| 17.0° | 180 | 114 |
| 17.9° | 200 | 127 |
| 18.6° | 220 | 139 |
| 19.4° | 240 | 152 |
| 20.0° | 260 | 165 |

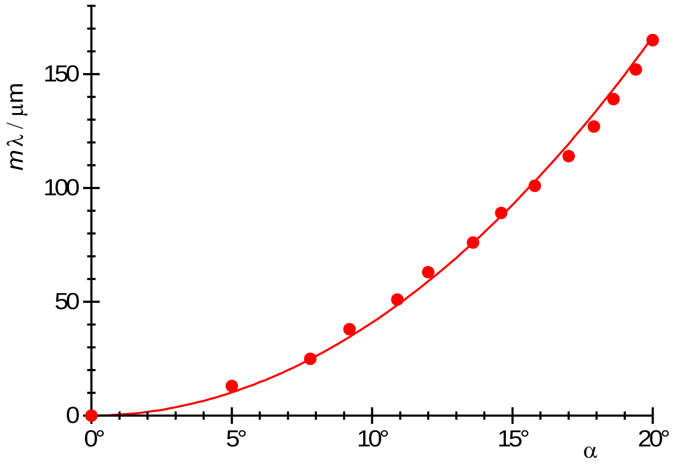


Fig. 2: Change in path length calculated from the number *m* of interference rings that disappear when a glass plate is rotated through the angle α

Figure 2 shows, as a function of α, the change in path length calculated from the number *m* of interference rings that disappear when a glass plate in the beam is rotated through the angle α from the position perpendicular to the beam. The wavelength used in the calculation was λ = 632.8 nm, the wavelength of the He-Ne laser.

The theoretical curve in Figure 2 was calculated from Equation 4, with the values *d* = 4 mm for the thickness of the plate and *n* = 1.5 for the refractive index of glass.

**Application of Twyman-Green interferometer to evaluate the surface quality of a strip of adhesive tape:**

On the right-hand side of the screen the interference rings are regular and well-defined. On the left-hand side, however, they are distorted and blurred, and sometimes there are bright dots in regions that should be dark and vice versa.

Since even very small differences in the thickness of a film can shift the interference rings, it is reasonable to conclude that the distortion of the rings is caused by the irregular and undulating surface of the adhesive tape.



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