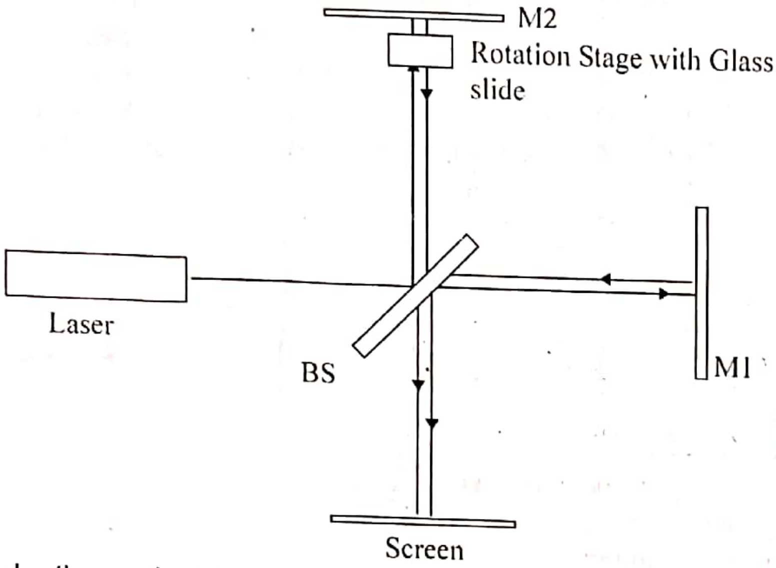
Michelson Interferometer - Exp - 02

Aim:- To calculate the Index of Refraction of Glass using Michelson interferometer.

Apparatus required: Breadboard, diode laser, laser mount, beamsplitter mount, mirror mount (2 numbers), Screen & Rotation stage with Glass mounted.

Theory:



In principle, the method for calculating the index of refraction is relatively simple. The light passes through a greater length of glass as the plate is rotated. The general steps for measuring the index of refraction in such a case is as follows:

1. Determine the change in the path length of the light beam as the glass plate is rotated. Determine how much of the change in path length is through glass, $d_g(\partial)$, and how much is through air, $d_a(\partial)$.
2. Relate the change in path length to your measured fringe transitions with the following equation:

$$\frac{2n_a d_a(\theta) + 2n_g d_g(\theta)}{\lambda_0}$$

where n_a = the index of refraction of air, n_g = the index of refraction of the glass plate (as yet unknown), λ_0 = the wavelength of your light source in vacuum, and **N** = the number of fringe transitions that you counted.

Carrying out this analysis for the glass plate is rather complicated, so we'll leave you with the equation shown below for calculating the index of refraction based on your measurements. Nevertheless, we encourage you to attempt the analysis for yourself. It will greatly increase your understanding of the measurement and also of the complications inherent in the analysis.

$$\frac{(2t - N\lambda_0)(1-\cos\theta)}{2t(1-\cos\theta) - N\lambda_0}$$

where **t** = the thickness of the glass plate.

Procedure:

1. Align the laser and interferometer in the Michelson mode.
2. Place the rotation stage between the beam-splitter and movable mirror, perpendicular to the optical path.
3. Mount the glass plate on the rotation stage.
4. Position the stage & glass such that degree is 0 & glass slide is perpendicular to the optical path.
5. When glass plate is introduced in the optical path of Michelson interferrometer, the fringe will be shifted & will become blur. To make the fringe sharpen again, move the Mirror mount to & fro till the clear set of fringes is achieved on the viewing screen.
6 . Slowly rotate the rotaton stage. Count the number of fringe transitions that occur as you rotate the table from 0 degrees to an angle q (at least 10 degrees).

Calibrating the Micrometer

For even more accurate measurements of the mirror movement, you can use our laser to calibrate the micrometer.

To do this, set up the interferometer in Michelson mode. Turn the micrometer knob as you count off at least 20 fringes. Carefully note the change in the micrometer reading, and record this value as d'. The actual mirror movement, d, is equal to $N\lambda/2$, where λ is the known wavelength of the light (0.6350 μm for our Diode Laser) and N is the number of fringes that were counted. In future measurements, multiply your micrometer readings by d/d' for a more accurate measurement.

Michelson Interferometer

Aim:- To calculate the wavlength of laser using Michelson interferometer.

Apparatus required: Breadboard, diode laser, laser mount, beamsplitter mount, mirror mount (2 numbers) , screen.

Theory:

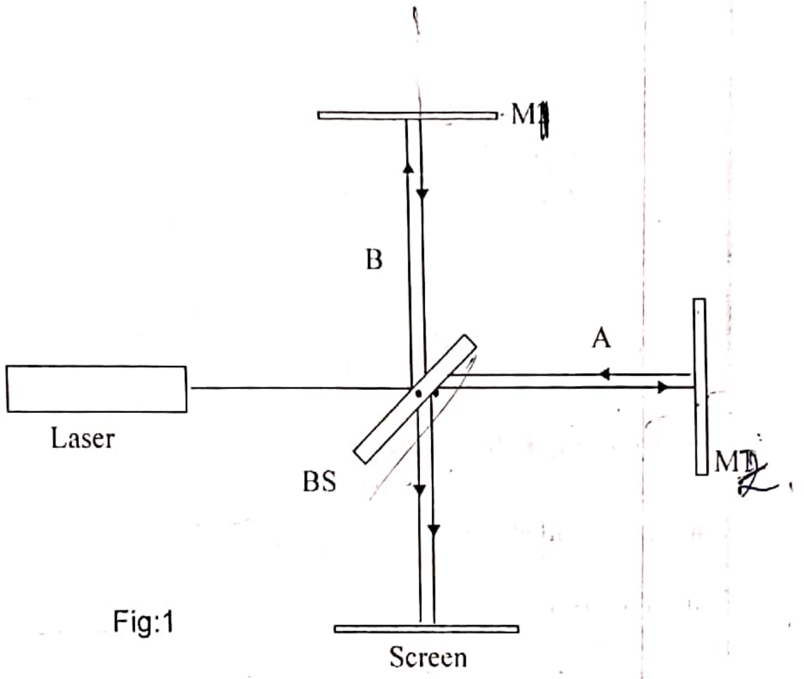


Fig:1

M_1 and M_2 are two plane mirrors silvered on the front surfaces. They are mounted vertically on two translation stages placed at the sides of an optical platform. Screws are provided at the back of the holders, adjusting of which allows M_1 and M_2 to be tilted. M_1 can also be moved horizontally by a micrometer attached to the M_1 holder. BS the 50% -50% beam splitter, is a planar glass plate slightly silvered on one side. It is mounted vertically and at an angle 45° to the direction of the incident light.

When light from laser is allowed to fall on BS, one portion, calling it beam A, is transmitted through BS to M_2 and the other, calling it beam B, is reflected by BS to M_1. Beam A, returning from M_2, is reflected at the back of BS to reach the screen placed at E and beam B, after reflected from M_1 passes through BS to reach the screen.

The wavelength of laser is calculated by :

$$\lambda = 2D / n \quad \text{..(Eq: 1)}$$

where D is the change in position that occurs 'n' fringes to pass.

Procedure:

1. Attach the diode laser with mount, adjustable mirror and moveable mirror as in the illustration, but don't install the beam splitter yet. Attach the viewing screen to as in figure.
2. Align the laser so that the beam is parallel with the top of the base. (The beam should strike the center of the moveable mirror and should be reflected directly back into the laser aperture.)
3. Position the beam splitter so that the beam is reflected to the fixed mirror. Adjust the angle of the beam splitter as needed so that the reflected beam hits the fixed mirror near its center.
4. There should now be two sets of bright dots on the viewing screen; one set comes from the fixed mirror and the other from the moveable mirror. Each set of dots should include a bright dot with two or more dots of lesser brightness (due to multiple reflections in the thin film of the beam splitter). Adjust the angle of the beam splitter again until the two sets of dots are as close together as possible, then tighten the screws securing the beam splitter and mirror mounts.
5. Using the leadscrews on the back of the adjustable mirror, adjust the mirror's tilt until the two sets of dots on the viewing screen coincide.
7. Expand the laser beam slowly by rotating the collimating lens on front the diode laser.
8. As a rule a streaky interference pattern, resulting from a non-parallel alignment of the two mirrors, is now already to be seen. Carry out a sensitive re-adjustment with the adjusting screws to bring the interference pattern to the wanted concentric form (Fig 2).
9. After aligning the laser with the interferometer and making certain that the fringes you are looking at move when the micrometer screw is turned, fix a position on the observing screen and note the micrometer reading.
10. Count the fringes that move past the fixed point (either outward or inward) as the screw is turned. Count at least 15 fringes as they pass the fixed point of the viewing region. Begin the counting with a hand on the thimble and try to exert a steady pressure.
11. Begin the counting with a hand on the thimble and note the initial reading on the thimble. After 15 fringes pass, note the reading on the micrometer scale and compute the distance the mirror moved.
12 In the movable mirror mount, it is mounted in a translation stage. The micrometer shaft actuates a *lever arm* which pushes the translation stage carrying the mirror. Here 10 micron on the thimble (one divison) is equal to .35 micron on the translation stage, ie when we move one step on the micrometer, mirror is moved to .35 microns.
13. Repeat the procedure 3 or 4 times. Average the readings.
14. Substitute the readings in the equation (Eq:1) to obtain results.

Notes: To avoid backlash in the micrometer move micrometer to one direction only while doing repetitive experiments.

Before taking the readings, observe the fringe movement.

Avoid moving the micrometer in reverse direction while doing an experiment.

Result: Observed the fringe pattern and calculated the wavelength of laser.

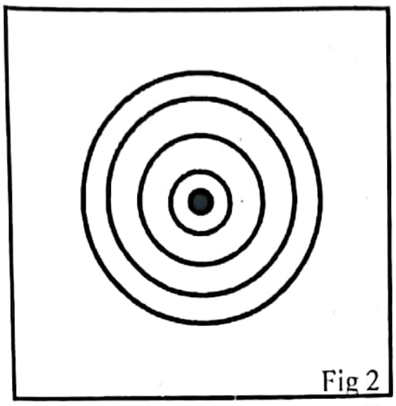
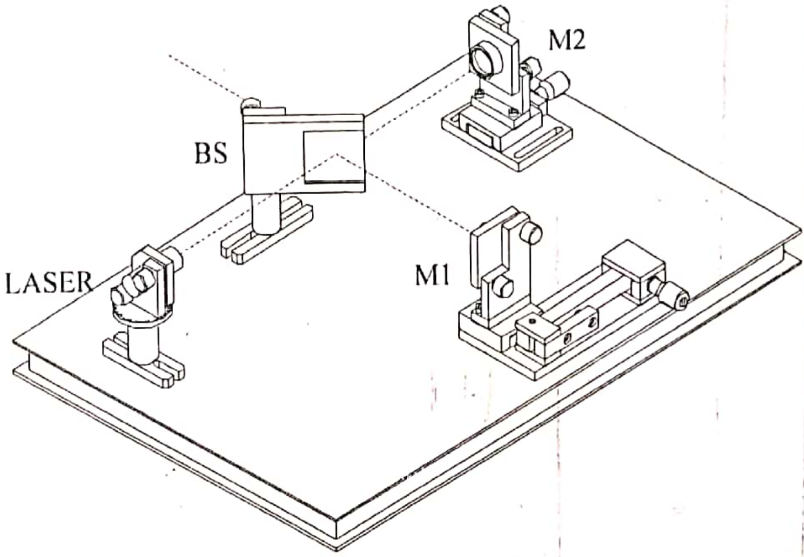


Fig 2

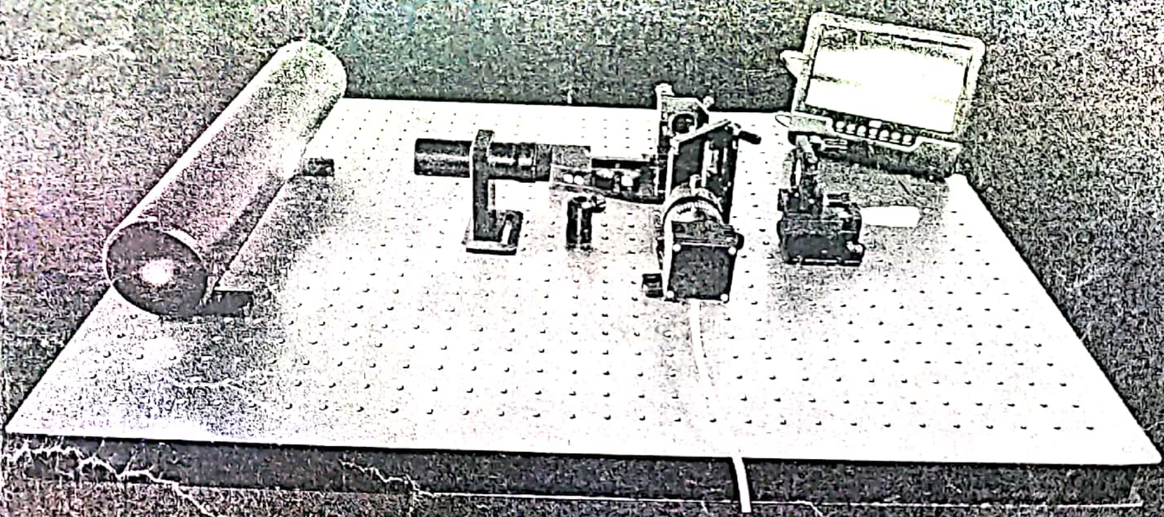


HOLMARC
OPTO-MECHATRONICS PVT. LTD

Michelson Interferometer

Sodium D Lines

Model: HO-ED-INT-06 S



Operating Manual

Product Features

In this model of Michelson interferometer, sodium vapor lamp is used as light source. Components are assembled on an Optical breadboard for setting up the experiment. Both the mirror mounts have kinematic adjustments and one of the mirror mounts is placed on a translation stage with fine and coarse adjustments. Diode laser is used for setting up the interferometer initially and the source is replaced by Sodium vapor lamp.

Getting Started

a. Quick Start

Please check if the following items are present while the instrument package is delivered.

1. Optical Bread board with Rigid Support
2. Diode Laser with power supply
3. Sodium vapor lamp with power supply
4. Kinematic Laser mount
5. Beam splitter with mount
6. Front coated Mirrors with mount (2no.)
7. Rotation stage
8. Glass slide
9. CCD with mount
10. LCD screen
11. Screen
12. Thumb screws

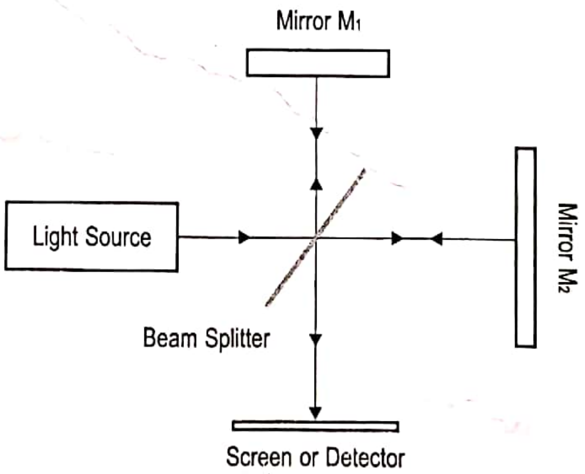
b. Safety and Installation Instructions

- Laser radiation predominantly causes injury via thermal effects; avoid looking directly into the laser beam.
- It is best that students work in low light dust free atmosphere.
- Care must be taken while handling the Optical components since this experiment uses precision optical lenses and other high quality components.
- Please don't put your fingers on the main optical surfaces but hold components by their edge.
- Always keep the equipment in a moisture and dust free atmosphere.

:: Fundamentals

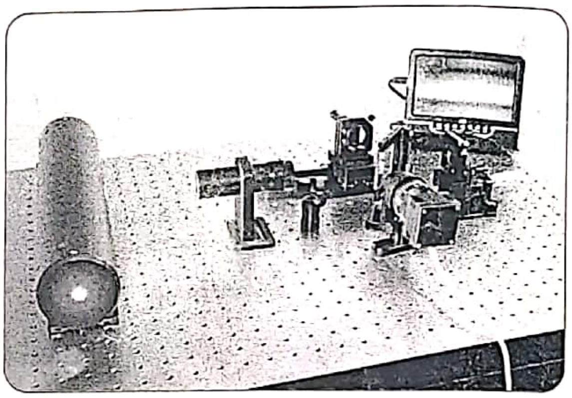
Aim :
1. To determine the wavelength of monochromatic light.
2. To find out the difference in wavelength of D_1 and D_2 lines of sodium light.

Theory :



M_1 and M_2 are two plane mirrors silvered on the front surfaces. They are mounted vertically on two translation stages placed at the sides of an optical platform. Screws are provided at the back of the holders. Adjusting of which allows M_1 and M_2 to be tilted. M_1 can also be moved horizontally by a micrometer attached to the M_1 holder.

The beam splitter, a planar glass plate partially silvered (50% - 50%) on one side. It is mounted vertically at an angle 45° to the incident light. When light from the source is allowed to fall on the beam splitter, one portion is transmitted through the beam splitter to M_1 and the other is reflected by beam splitter to M_2. The reflected beams from M_1 and M_2 superimpose at the beam splitter and interference pattern can be observed on the screen.



The two beams of a Michelson interferometer interfere constructively when the waves add in phase and destructively when they add out of phase, producing circular interference fringes as a result. With Sodium source the wavelength is given by

$$\lambda = (2d / N)\,\Delta,$$

Where 'd' is the change in position that occurs 'N' fringes to pass and Δ is the calibration constant of the micrometer.

The interference pattern observed with the sodium lamp contains twc sets of fringes which disappear when the bright bands of one set are superimposed on the dark bands of the other.

The wavelength separation of the Na D-line doublet is easily determined by observing the successive coincidence and discordance of the two sets of fringe systems produced by the doublet of wavelengths (λ_1 and λ_2 with $\lambda_1 > \lambda_2$). As D is increased, the two systems gradually separate and the maximum discordance occurs when the rings of one system are set exactly halfway between those of the other system. The discordance positions are most clearly seen as minima in the contrast of the pattern. Then the wavelength separation $\lambda_1 - \lambda_2$ is given by

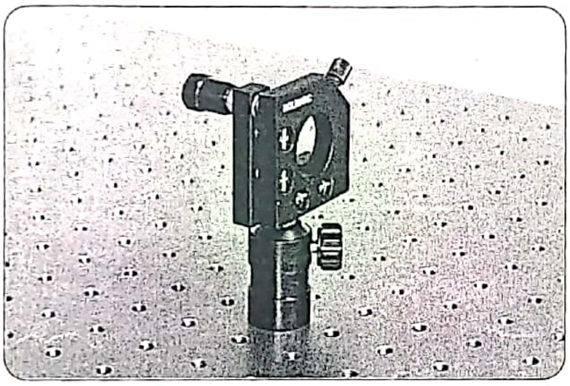
$$\lambda_1 - \lambda_2 = \lambda_1 \lambda_2 / 2D$$

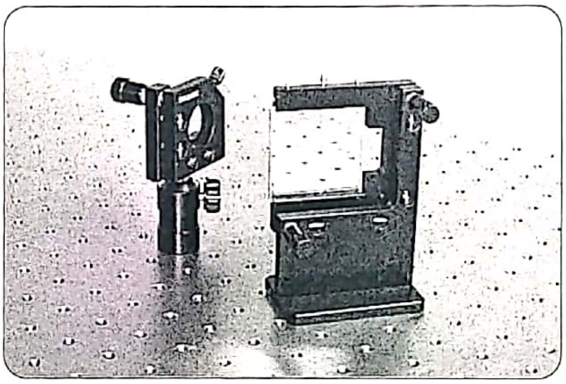
$$\lambda_1 - \lambda_2 \approx \lambda^2 / 2D$$

Where λ is the average wavelength of Sodium, D is the is the change in position of the micrometer for two successive discordance / coincidence.

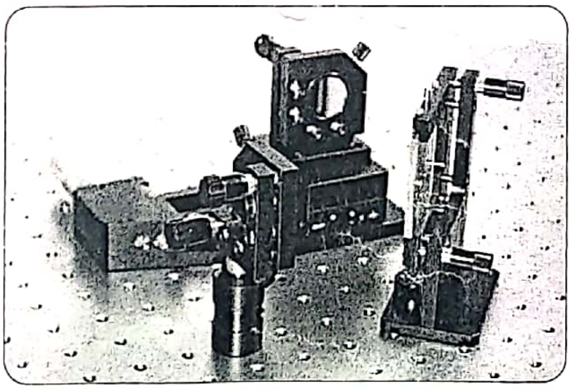
:: Experimental Set-up

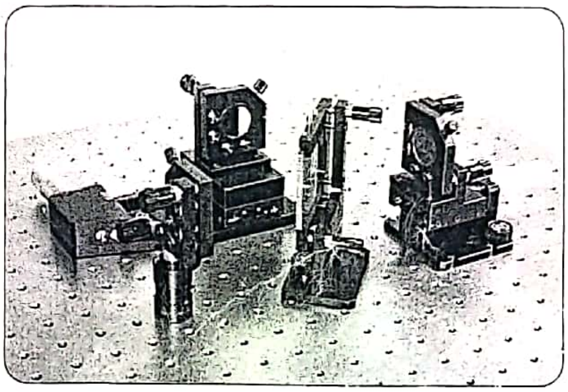
1. Fix the laser mount on the bread board and place the beam splitter at 45°





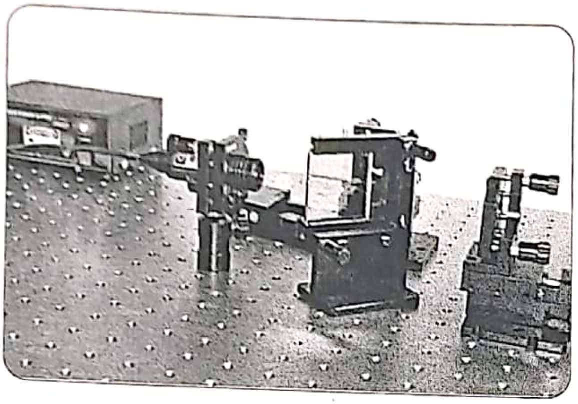
2. Fix the high precision mirror with translation stage (M_1) & mirror with coarse movement (M_2) in equal distance from the beam splitter.

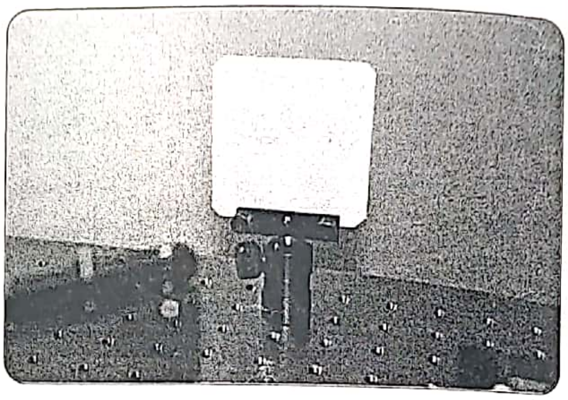




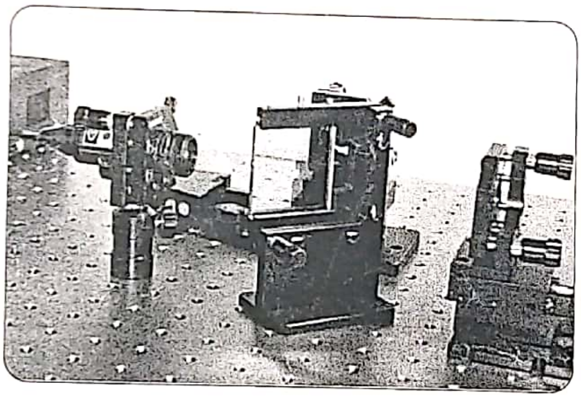
λ₂

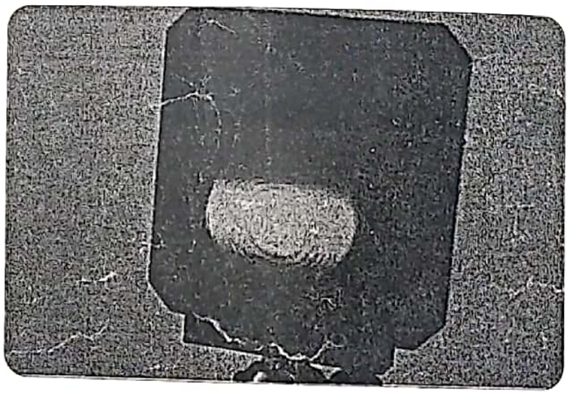
3. Insert the laser (remove the lens of the laser) & Screen with mount. You can see two bright spots on the screen. Using tilt adjustment provision on the beam splitter mount and mirror mount coincide the two spots.



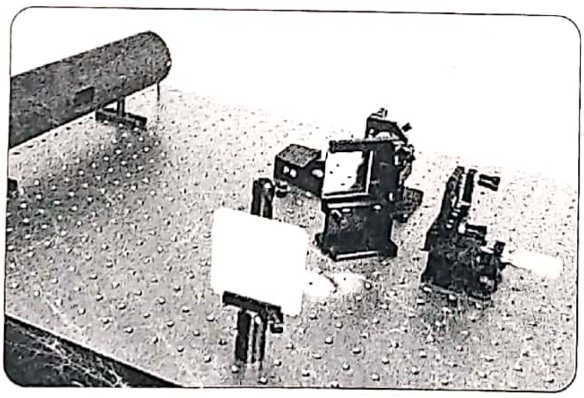


4. Insert the lens in front of the laser. Observe the clear circular fringes on the screen.

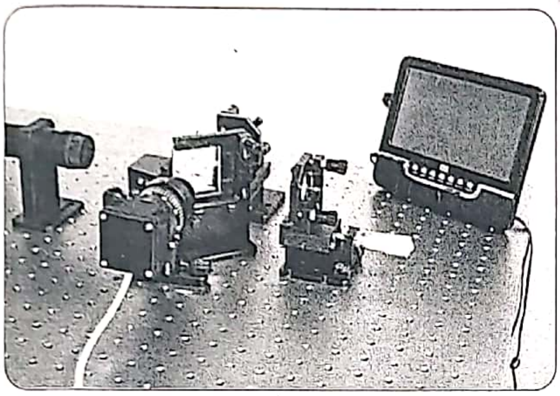


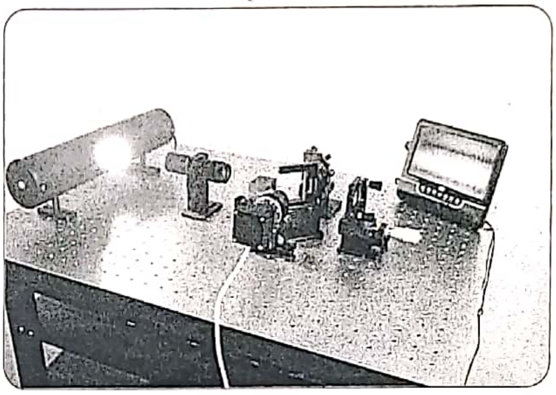


5. Remove the laser and insert the Sodium Lamp and the collimator.

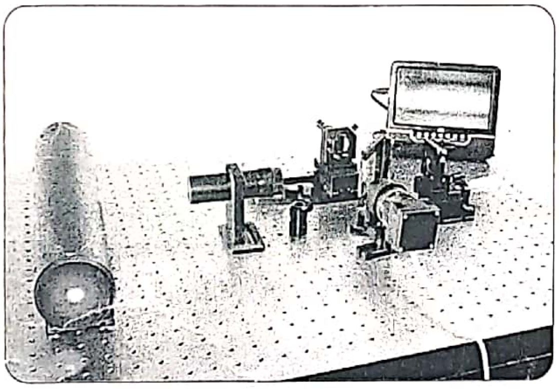


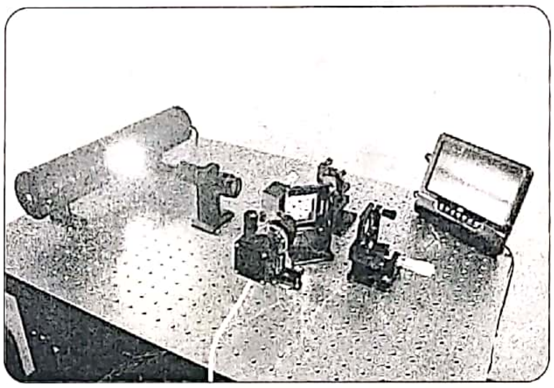
6. Replace the screen with camera. Observe the fringe pattern on the display.





7. Adjust the mirror tilt and position of the camera for clear and sharp circular fringes.





Procedure

To determine the wavelength of monochromatic light.

1. Firstly set up the Michelson interferometer with laser. You will get clear circular fringes.
2. Rotate the micrometer of high precision mirror translation stage (M_1) to count 20 nos. of fringes and note down the distance moved for 20 fringes. This distance is taken as 'd'.

3. We know the wavelength of laser $\lambda = 650nm$ and $N = 20$ nos.

We have the equation, $\lambda = (2d / N)\Delta$

$$\Delta = \lambda / (2d / N)$$

So we can find out the calibration constant of the micrometer.

4. Replace the laser with Sodium lamp and screen with camera. You can see the clear circular fringes on the LCD display.

5. Rotate the micrometer of the high precision mirror translation stage and find the distance moved for 20 nos. of fringes. This distance is taken as 'd'. We also know N=20 nos. and Δ from above calculation.

6. Then we can find out the wavelength of sodium light by using the equation

$$\lambda = (2d / N)\Delta$$

To determine the wavelength separation between D_1 & D_2 lines of Sodium light.

1. Firstly set up the Michelson interferometer with sodium light and get the clear circular fringes.

2. Then rotate the micrometer of the mirror translation stage (M_2) and you can see that the fringes are most clear at certain positions of the micrometer. In some other positions of the micrometer you can notice that the fringes disappear.

3. When the sodium D lines are in phase together, the fringes are clear and sharp. When one line is in phase at a point but the other is out of phase, and vice versa, the fringes are washed out and indistinct

4. So note the reading of the micrometer when there are no fringes.

5. Then rotate the micrometer to get the same condition (no fringe) again. Note this position of the micrometer.

6. Find the difference and take this as D (change in position of the micrometer for two successive discordance / coincidence.)

7. Then wavelength separation $\lambda_1 - \lambda_2 = \lambda^2 / 2D$
   where λ is the average wavelength of the sodium.

Measurements

1. Calibration Constant

Wavelength of laser λ = ...

Least count of the micrometer = ...

Trial No	Fringes Moved (N)	Micrometer reading		Distance Moved (d) mm	Calibration Constant $\Delta = (\lambda N / 2d)$
		Initial	Final		
1.					
2.					
3.					
4.					

Average Calibration Constant Δ = ...

2. Combined wavelength of Sodium

Trial No	Fringes Moved (N)	Micrometer reading		Distance Moved (d) mm	Wavelength $\lambda = (2d / N) \Delta$ nm
		Initial	Final		
1.					
2.					
3.					
4.					

Average wavelength λ = ...nm

3. **Wavelength separation of D_1 and D_2 lines of Sodium**

Trial No	Micrometer reading		Distance Moved (d) mm	$\lambda_1 - \lambda_2 = \lambda^2 / 2D$ nm
	Initial	Final		

Average $\lambda_1 - \lambda_2$ = ...nm

Result :

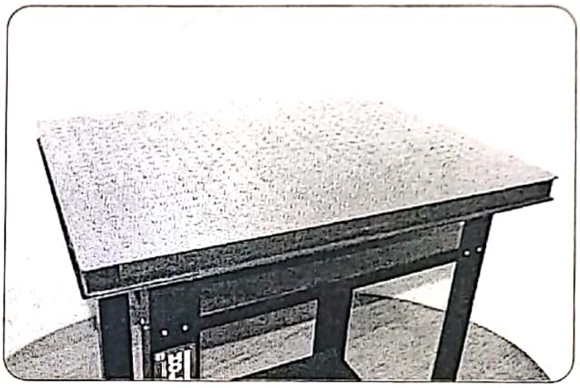
1. The wavelength separation of D_1 and D_2 lines of sodium is ....
2. Error percentage ....

Items included with Specifications

1. Optical Bread Board with Support

Dimensions : 800mm x 600mm

Material : Stainless Steel

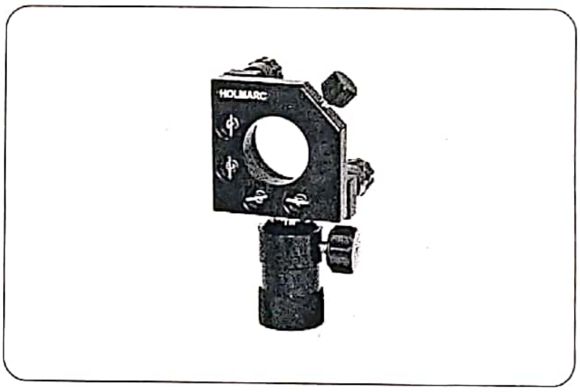


2. Kinematic Laser Mount

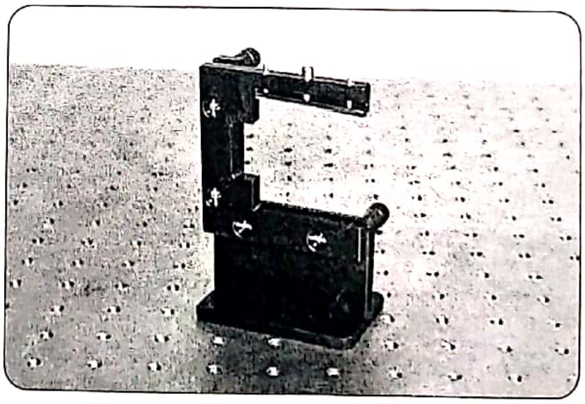
Fine adjustments : Using 80 tpi leadscrews

Adjustment Range : +/-4 degrees

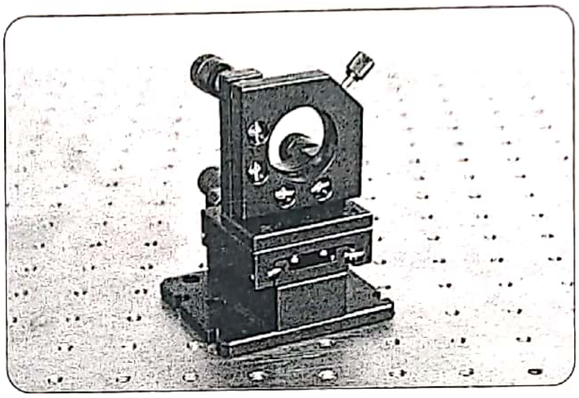
Material : Black anodized Aluminum alloy



3. Beam splitter Mount

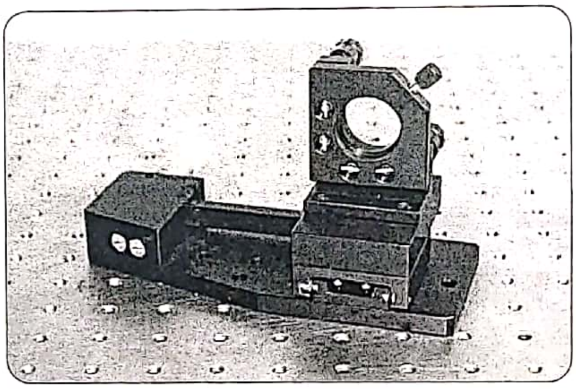


4. **Movable Mirror Mount**

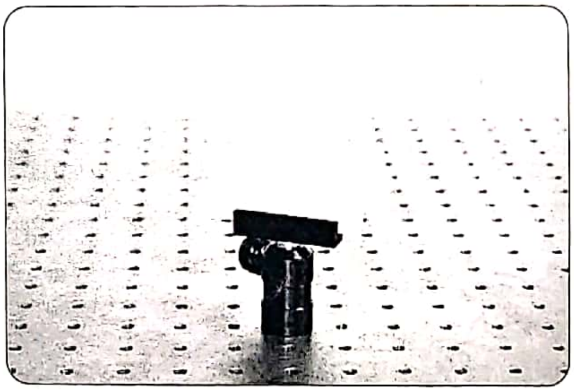


5. **Mirror Mount with Precision Translation**

Least count of the micrometer: 0.01mm

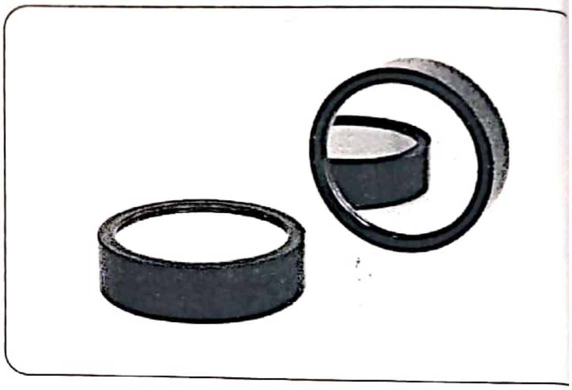


6. **Screen with mount**



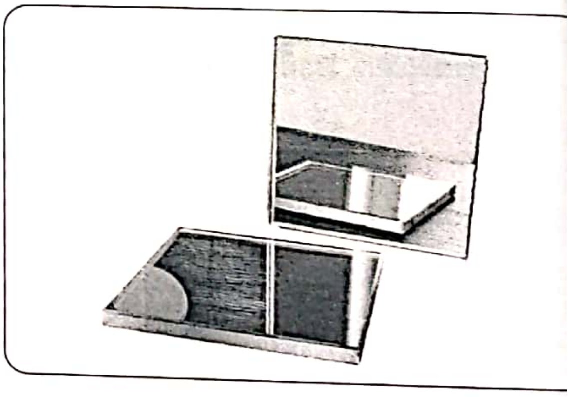
7. **Front Coated Mirror**

Diameter: 25mm
Thickness: 6mm
Material: Borofloat
Coating: Aluminum

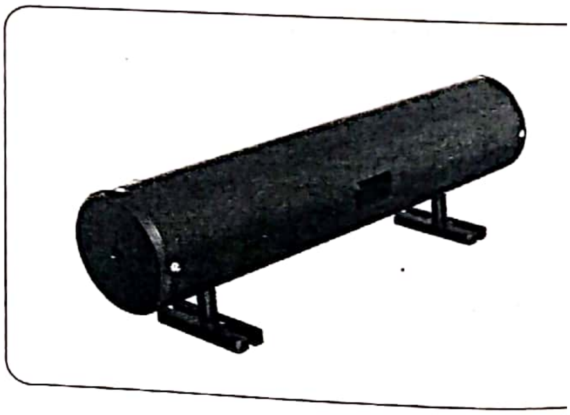


8. **Beam Splitter**

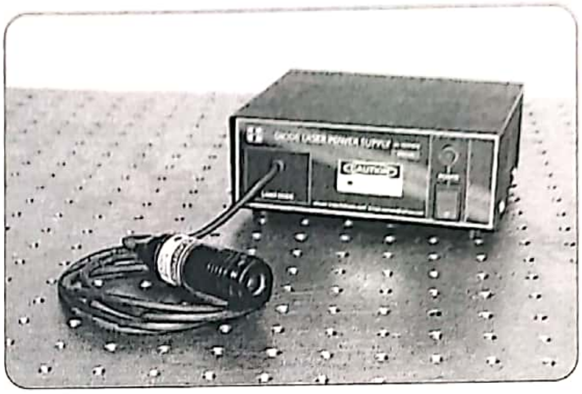
Dimension: 50mm X 50mm
Thickness: 4mm
R/T ratio : 50/50
Material: Bk7
Coating: Aluminum



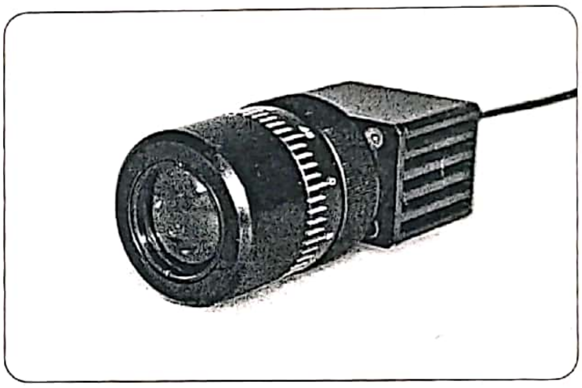
9. **Sodium vapour lamp with power supply**



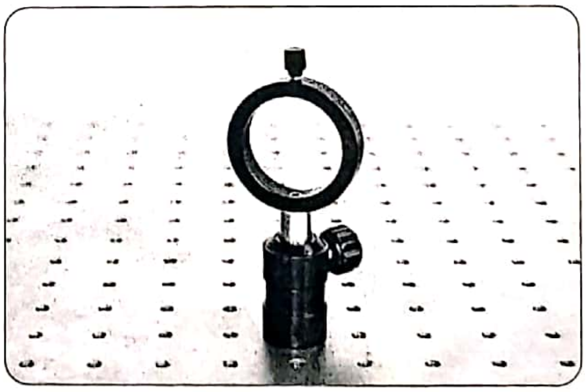
10. **Diode laser with power supply**



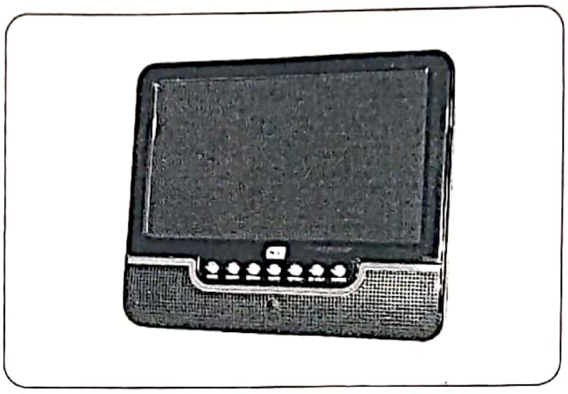
11. **CCD camera**



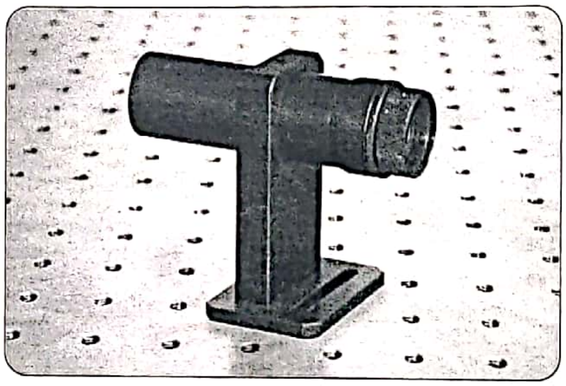
12. **CCD camera mount**



13. **LCD display**



14. **Collimator**



Maintenance Notes

- Always keep the equipment in a moisture and dust free atmosphere.
- Do not touch the active region of polarizer and other optical components with bare hands
- 'Switch on' all the electronic devices used in this experiment at least once in a week.

Technical Support

Before you call the HOLMARC Technical Support staff, kindly gather the following information:

- Title and model number (usually listed on the label)
- Approximate age of apparatus
- Detailed description of the problem / sequence of events
- Have the manual in hand to discuss your query

Feedback

If you have any comments regarding our product or manual, please let us know. If you have any suggestions on alternate experiments or find a problem in the manual, kindly inform us. HOLMARC appreciates any customer feedback. Your inputs help us evaluate and improve our product.

For technical support, contact us at
Ph: 91-484-254-0075
Fax: 91-484-254-3755
E-mail: mail@holmarc.com
Web: www.holmarc.com

:: Mechanical Drawing