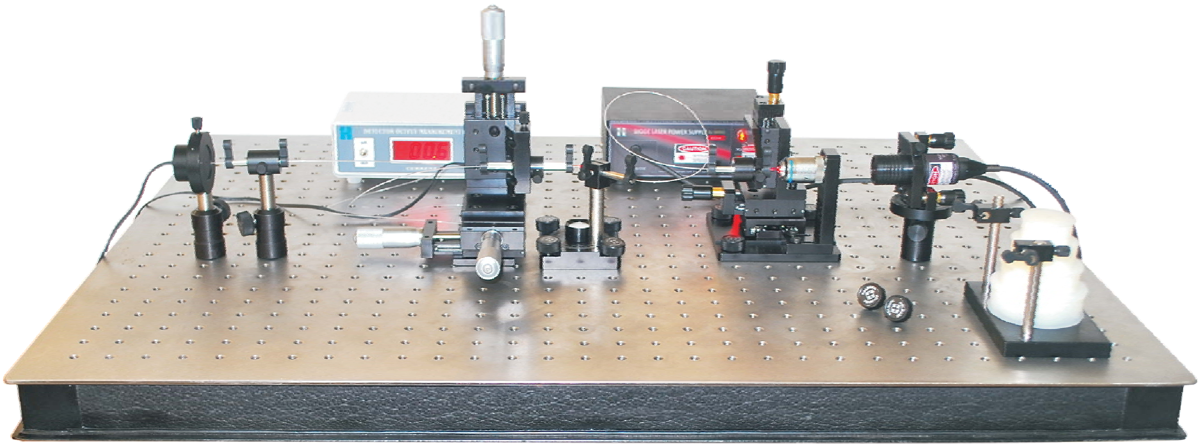
Experiment # 9

I. Study of total internal reflection & calculation of the refractive index of PMMA rod

II. Multimode mode Fiber Characterization



b. Installation & Safety Instructions

- Laser radiation predominantly causes injury via thermal effects; avoid looking directly into the laser beam.
- It is recommended that students work in low light dust free atmosphere.
- Care must be taken while handling the Optical fiber.
- Always keep the equipment in a moisture and dust free atmosphere.

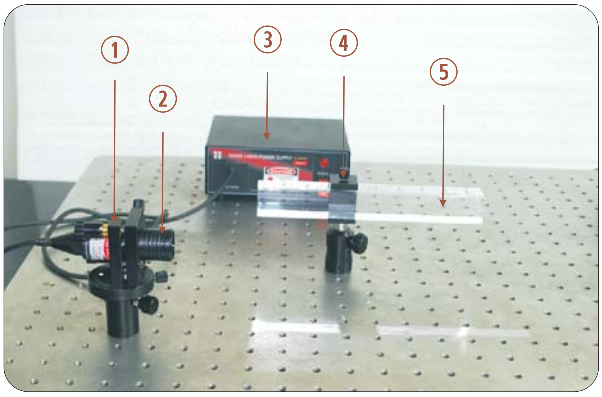
Study of total internal reflection & Calculation of refractive index of PMMA rod

Total internal reflection is an optical phenomenon that happens when a ray of light strikes a medium boundary at an angle larger than critical angle with respect to the normal to the surface. If the refractive index is lower on the other side of the boundary and the incident angle is greater than the critical angle, no light can pass through and all of the light is reflected.

Aim : To find the refractive index of a transparent solid using diode laser.

Parts Listing :

1. Kinematic Laser mount
2. Diode Laser
3. Power Supply for laser
4. Mount for PMMA rod
5. PMMA rod



Theory : According to Snell's law,

$$n = \sin i / \sin r$$

where, n is the refractive index of transparent medium, '**i**' is the angle at which light enters the medium and '**r**' is the angle at which it gets refracted.

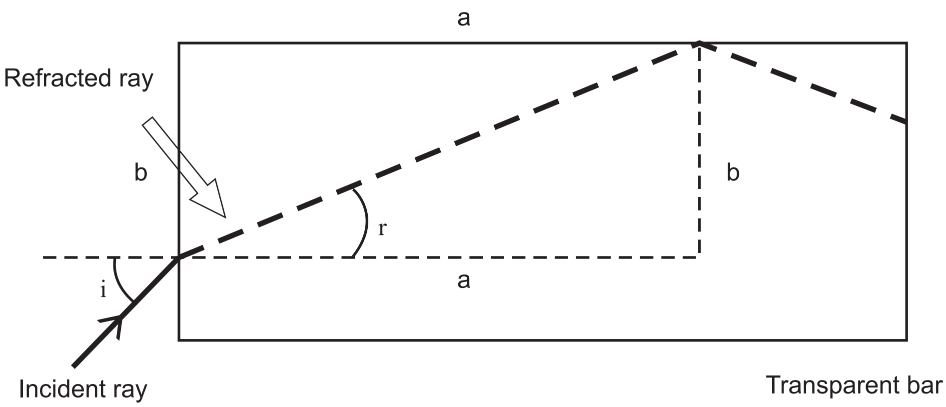
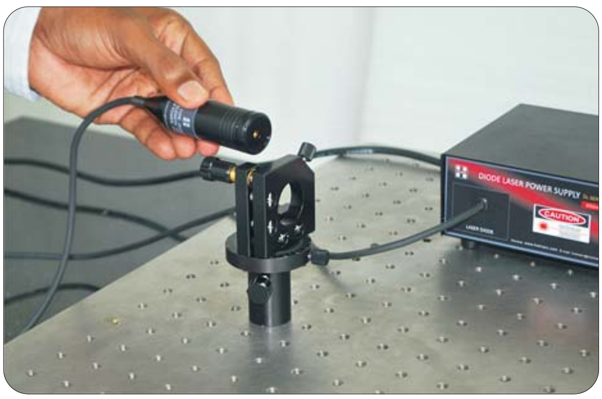
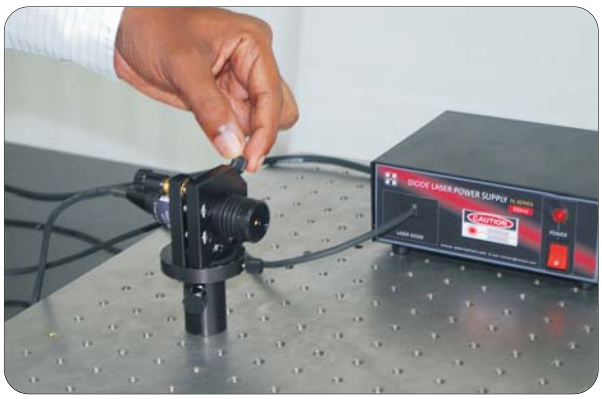


Figure (1)

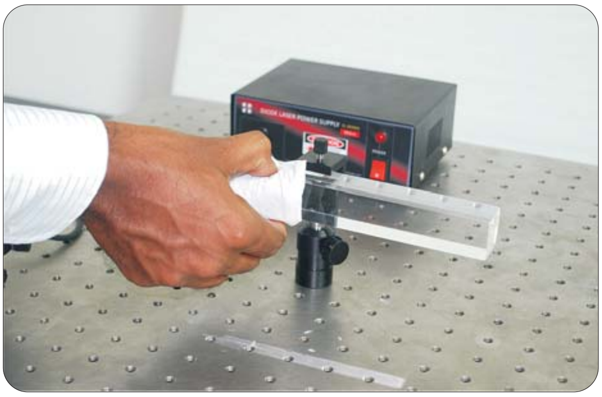
Experimental Set-up :

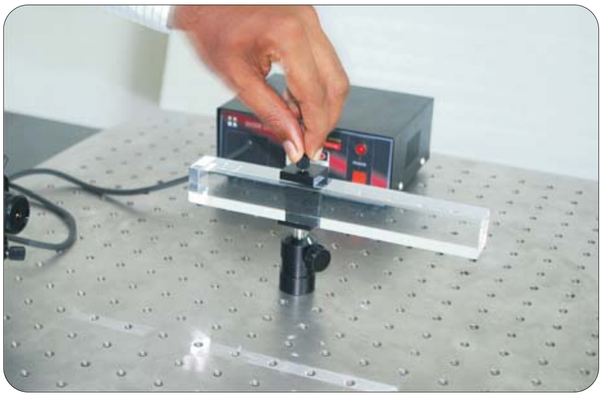
1. Fix the kinematic laser mount on the bread board and mount the laser properly.

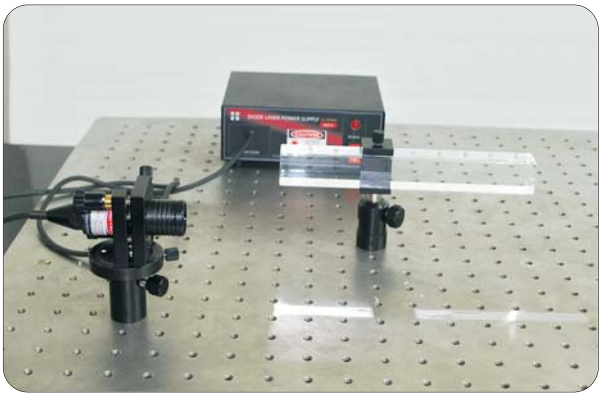




2. Mount the PMMA rod on the optical bread board.

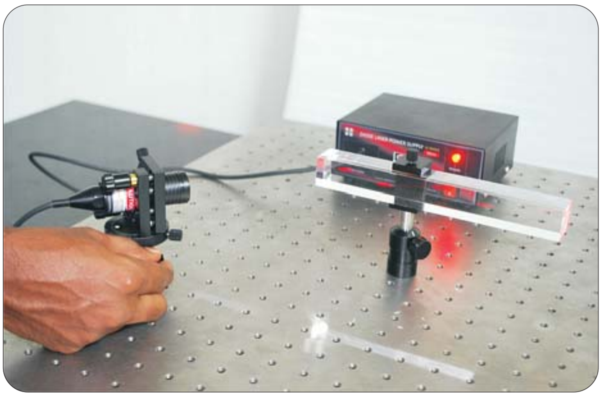




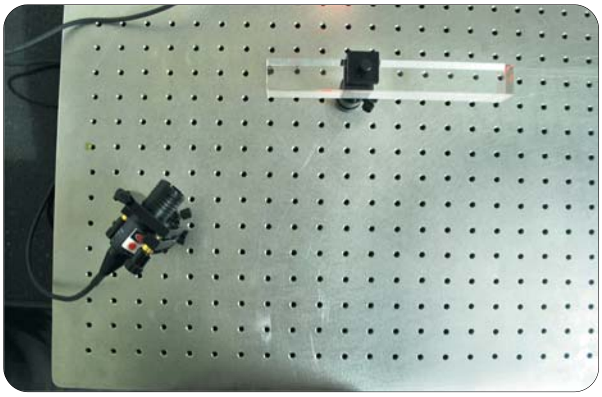


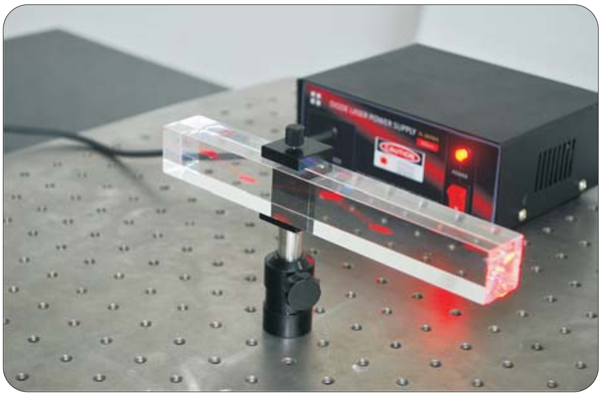
Procedure :

1. Make sure that the laser beam is exactly parallel to the PMMA rod. Rotate laser so that beam falls on the PMMA rod at an angle as shown in the figure. Fine adjustment can be done to get the angle for total internal reflection.



2. Note down incident angle of laser beam directly from the dial on laser mount. Measure the distances **a** and **b** using a meter scale. (Refer figure 1)





3. Repeat the experiment by changing the angle of incidence.

Measurements :

Trial No:	Angle of incidence (i)	a cm	b cm	$r = \tan^{-1}(b/a)$	Sin r	Sin i	n = sin i/sin r

Mean refractive index n = …………

Result :

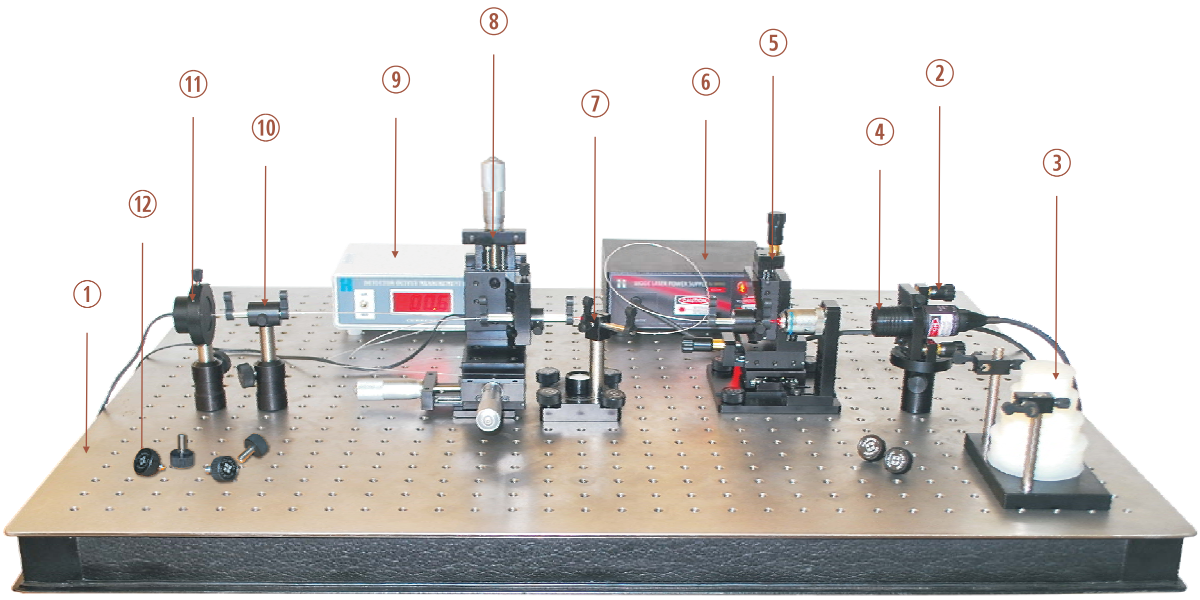
The refractive index of the solid n = …………

Multimode Fiber Characterization

Aim :

1. To determine numerical aperture of a given optical fiber.
2. To study the bending loss in a multimode optical fiber.
3. To determine Splice Loss
    a. Transverse offset between the fiber ends.
    b. Longitudinal separation between the fiber ends.
    c. Angular tilt between the fiber ends.

Parts Listing :

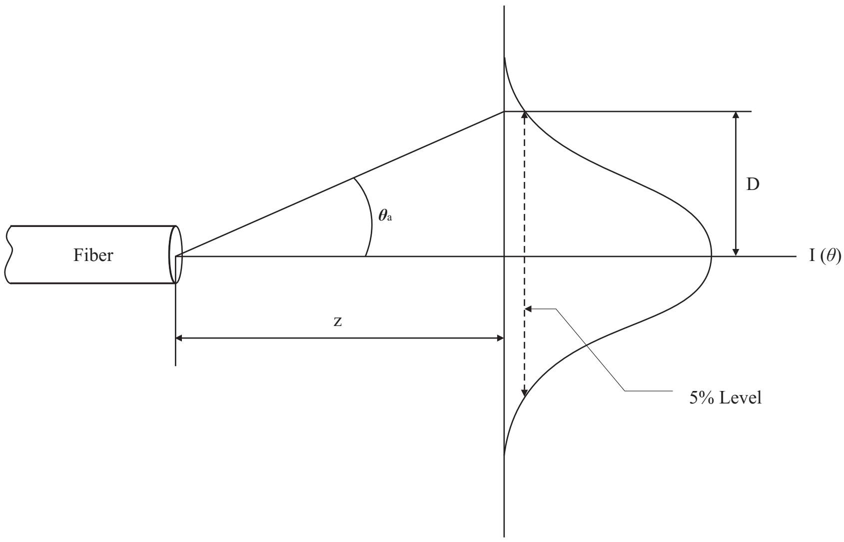


1. Optical Bread board with rigid support
2. Kinematic Laser Mount
3. Bending loss apparatus
4. Diode laser
5. Laser-Fiber Coupler with multi axis - translation stage
6. Laser Power Supply
7. Rotation stage with fiber chuck
8. XYZ translation stage
9. Pinhole detector o/p Measurement unit
10. Fiber chuck holder
11. Cell Mount with pinhole detector
12. Thumb screws

:: Numerical Aperture

Theory :

A multi-mode optical fiber will only propagate light that enters the fiber within a certain cone, known as the acceptance cone of the fiber. The half-angle of this cone is called the acceptance angle, θ_a.



Acceptance angle

$$\theta_a = \tan^{-1}(D/Z)$$

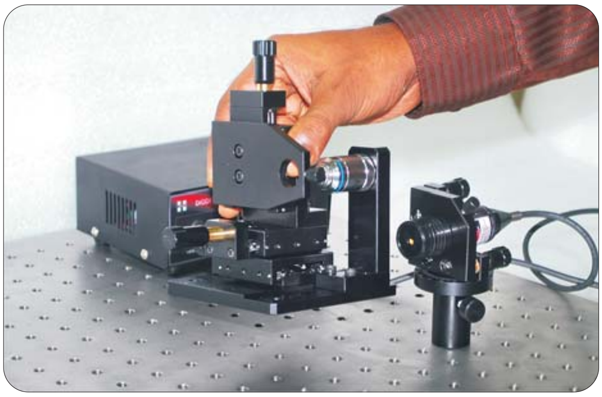
where, **D** is the diameter of far field intensity at 5% intensity level of the maximum attainable intensity and **Z** is the distance between the detector and the fiber output end.

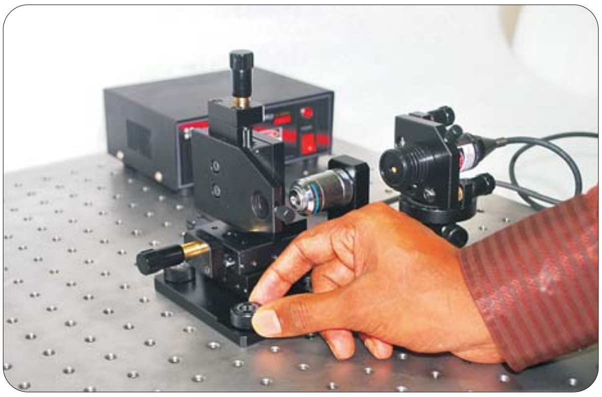
The Numerical Aperture is given by,

$$NA = \sin\theta_a$$

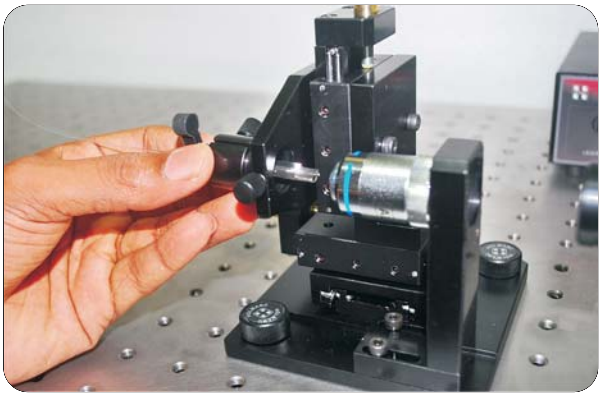
Experimental Set-up :

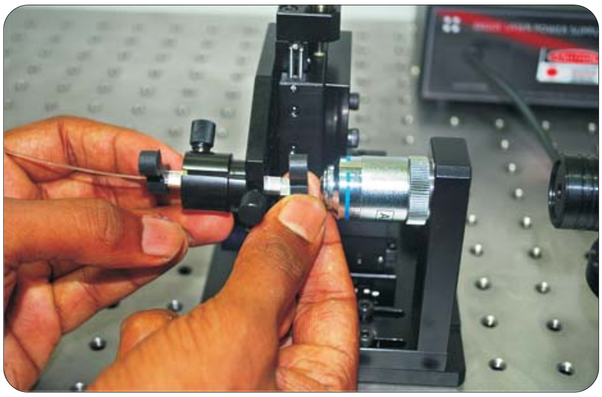
1. Fix the kinematic laser mount on the optical breadboard and mount the diode laser carefully. Then fix the laser fiber coupler properly using thumb screws.

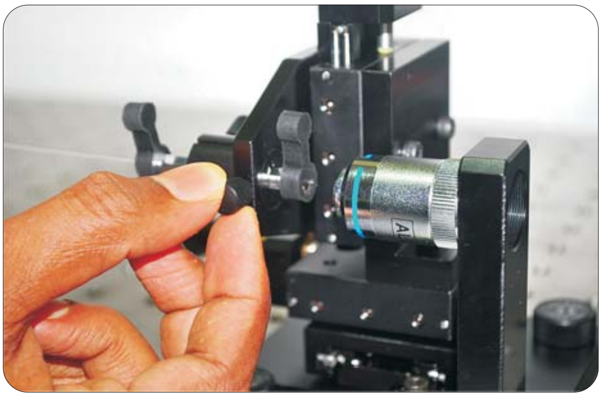




2. Fix one end of the optical on the chuck and mount it on the multi axis translation stage.

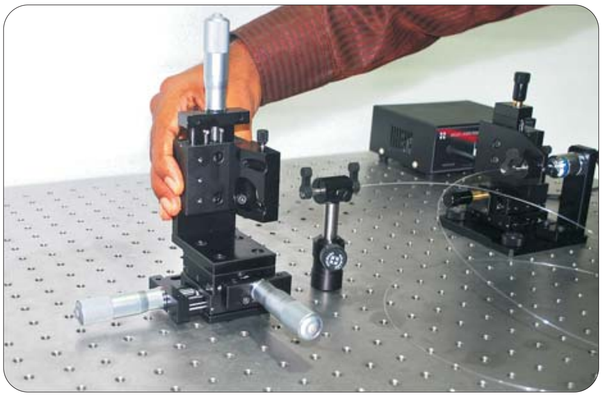


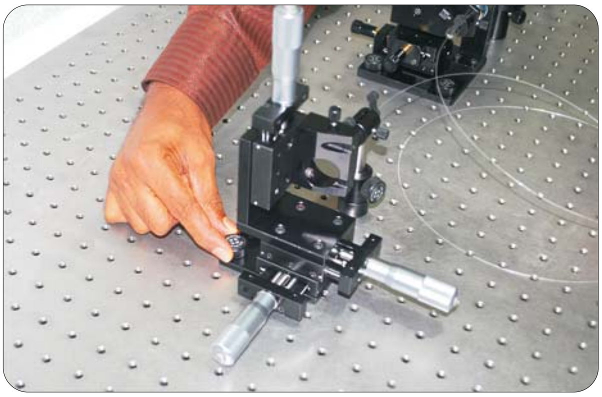


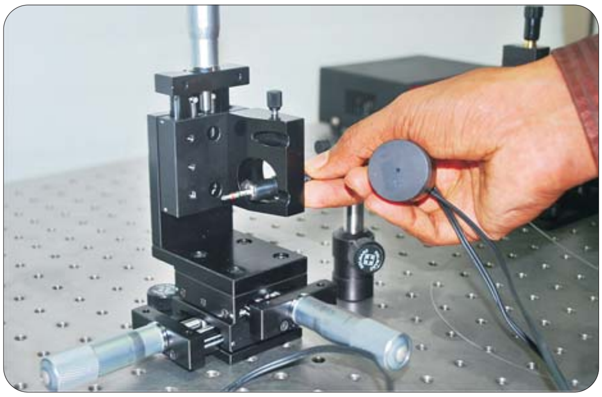


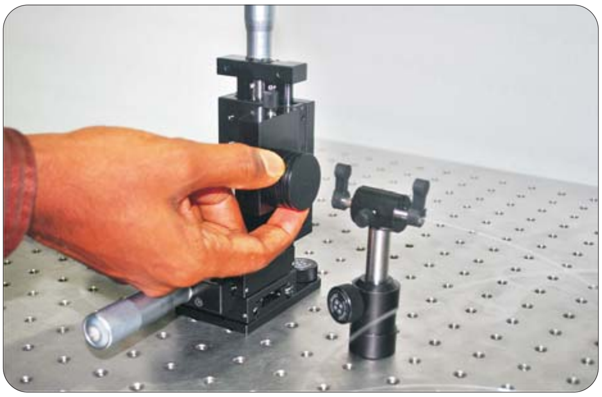
3. Mount the fiber chuck holder and insert the other end of the optical fiber and hold it as shown below.

4. Place XYZ translation stage and fix it on the bread board. Mount the pinhole photo detector on the stage.

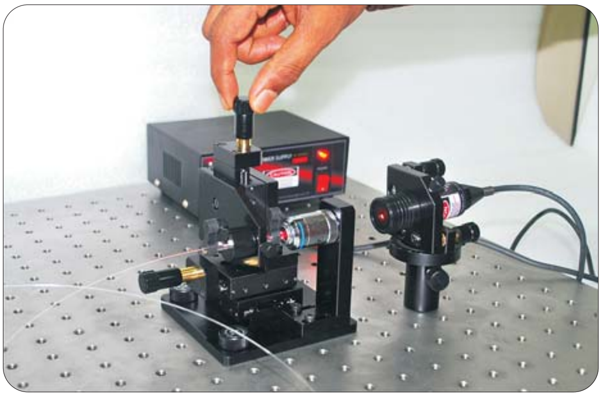




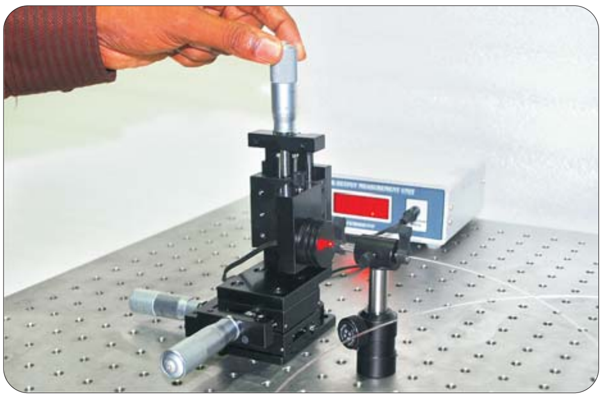


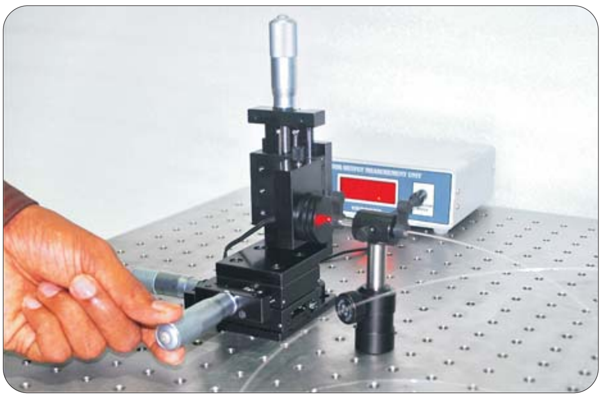


5. Switch on the laser and detector. The pinhole detector should be placed very close to the fiber tip. Using the multi translation stage and lead screws provided on the kinematic laser mount couple maximum light to the fiber.



6. Make sure that the o/p from the fiber is maximum. For this move the detector in X and Y direction till the detector shows the maximum o/p current. After that adjust the diode laser using the lead screws and the laser fiber coupler till you obtain maximum current in the o/p measurement unit of the detector.



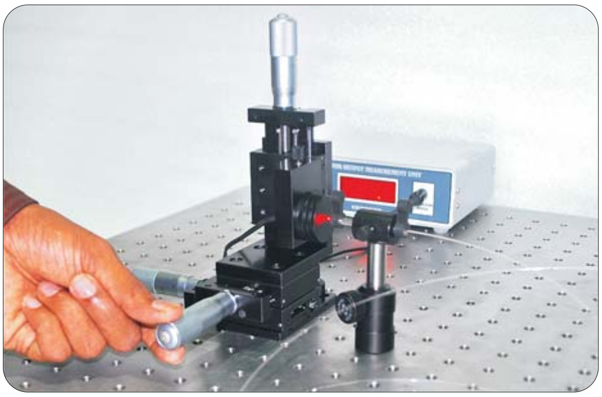


Note: *Change the range of the O/P measurement unit to µA from mA and vice versa whenever necessary.*

Procedure :

1. Bring the pinhole detector very close to the tip of the fiber using the Z micrometer provided on the translation stage, i.e. almost zero distance between the tip of the fiber and the pinhole detector. Note down the reading on the **Z** micrometer. Move the detector backwards using the **Z** micrometer (say 2 or 3mm) and again note down the reading. The difference between the two readings gives the '**Z**'.

2. Move the detector to right or left extreme using the X micrometer. Then scan the entire beam in X direction. Each time note down the micrometer reading and o/p current from detector.



3. Plot a graph "micrometer reading versus o/p current". From the graph we can find D.

Measurements :

Least count of the micrometer = ………………

Sl No:	Micrometer reading (mm)	Detector o/p current

From graph,

Diameter of far field intensity at 5% intensity level of the maximum attainable intensity, D = …………

Distance between the detector and the fiber output end, Z = ……..

Acceptance angle, $\theta_a = \tan^{-1}(D/Z)$ = ………..

Then the numerical aperture is given by,

$$NA = \sin \theta a = \ldots\ldots\ldots$$

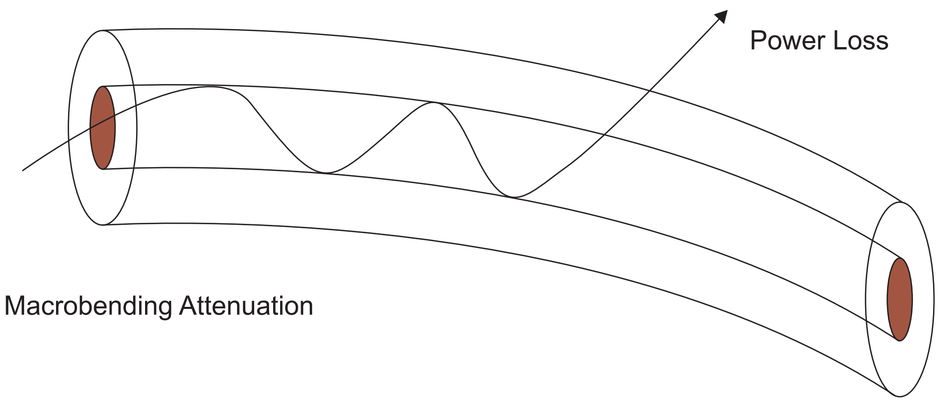
Result :

The Numerical Aperture of the given optical fiber, NA = ………………

Bending Loss

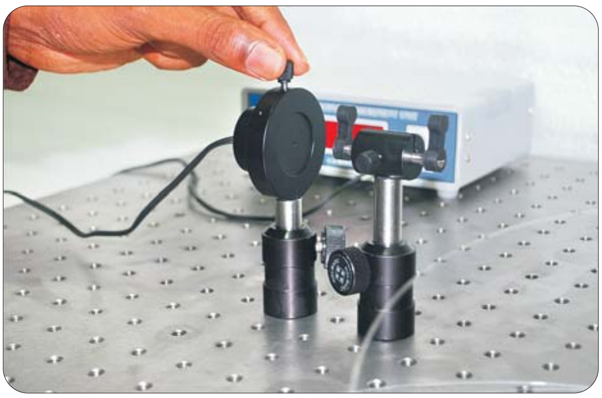
Theory :

The bend of a fiber causes loss in transmittance and increase in attenuation as the angle of incidence decreases at the points where curveted radius is too small and the condition of total internal reflection is not fulfilled. In this experiment an apparatus of varying radii is used to study the bending losses involved. When a fiber is bend specified number of turns on various diameters, loss occurs in accordance with the diameter and it can be seen that, the loss will increase with respect to the decrease in diameter.



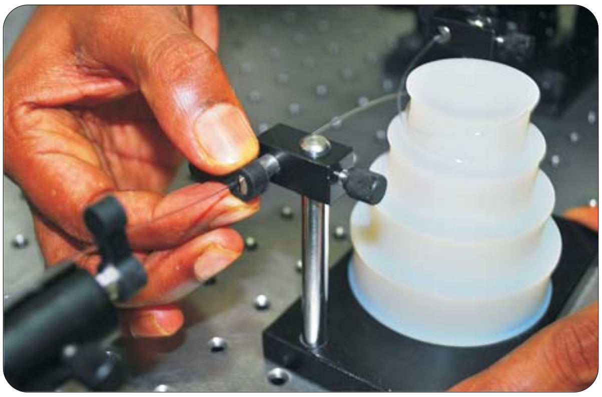
Experimental Set-up :

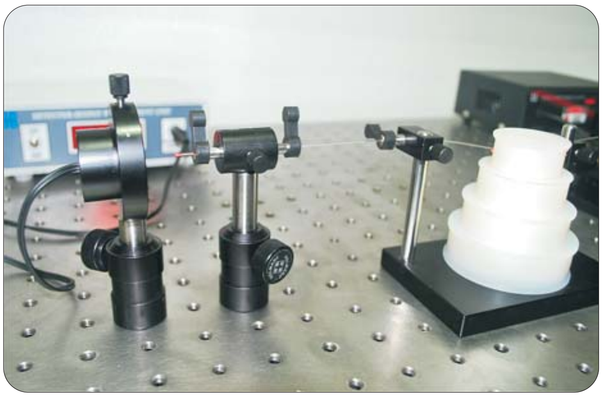
1. XYZ translation stage in the above experiment (experiment to find the numerical aperture) and fix the cell mount. Mount pinhole photo detector on to cell mount.



2. Place the bending loss apparatus in between the laser fiber-coupler and fiber chuck holder. For bending loss experiment we have to use a longer fiber. Fix the fiber to the bending loss apparatus as shown in figure. The end of the fiber connected at the laser - fiber coupler mount should not be disturbed while fixing the other end on the bending loss apparatus.

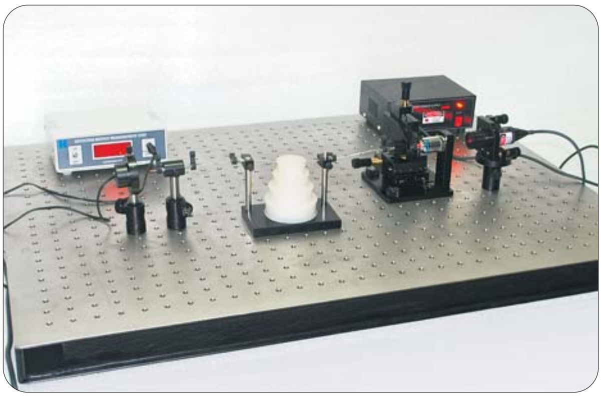
3. Wound the fiber on any of the circular diameter and connect the end to the fiber chuck holder fixed near the detector.





Procedure :

1. Take the output reading from the detector. Then increase the number of turns and take the corresponding readings. Repeat the experiment by changing number of turns or diameter.



Measurements :

Sl No:	Diameter (cm)	No. of turns (N)	O/P current from the detector (μA)

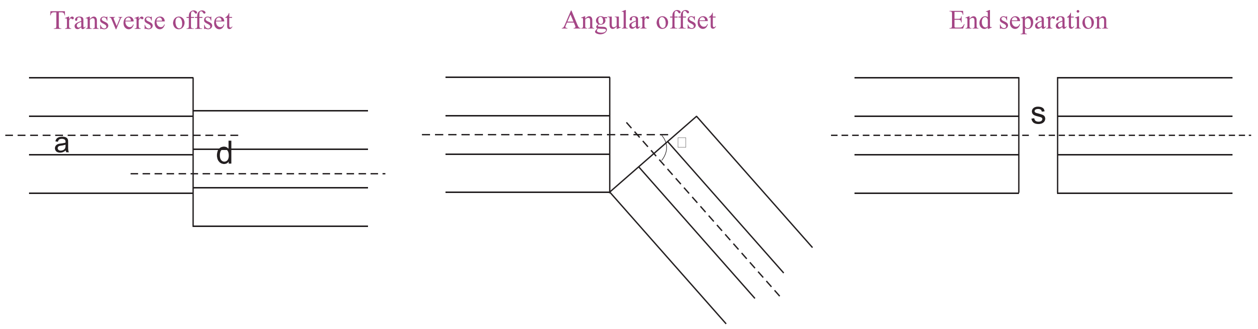
Result :

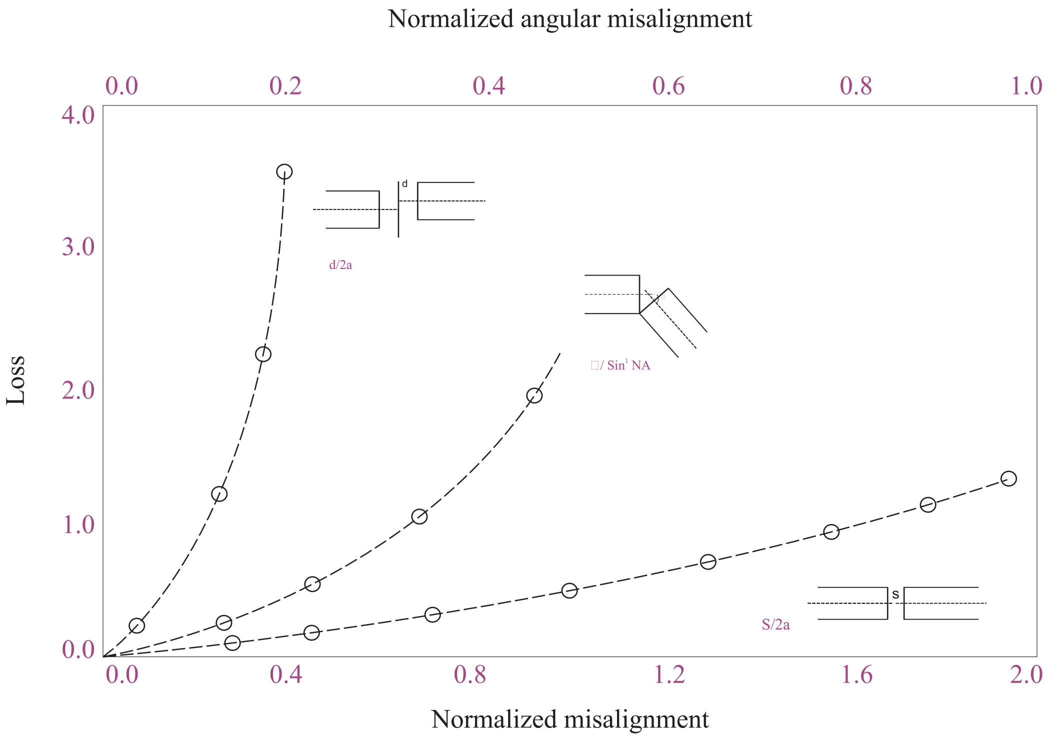
Observed the bending losses in a multimode fiber when it is bent along various diameter and found that the losses increase with decrease in diameter of bend.

Splice Loss

Theory :

Optical power loss at the splicing point of two ends of optical fiber is known as splice loss.



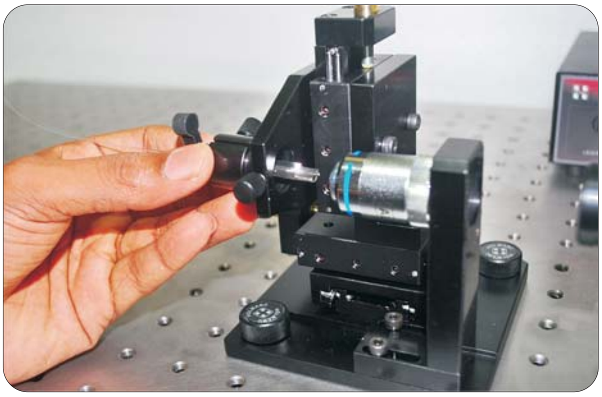


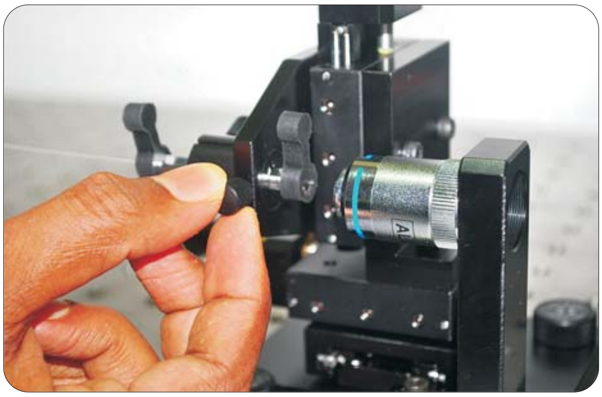
Typical results of splice losses due to various offsets between two multimode fibers

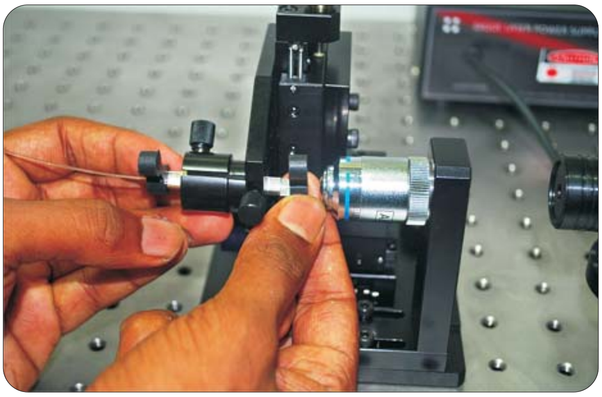
Experimental Set-up :

1. Mount the laser on the breadboard using the laser mount and fix the laser-fiber coupler on the breadboard.

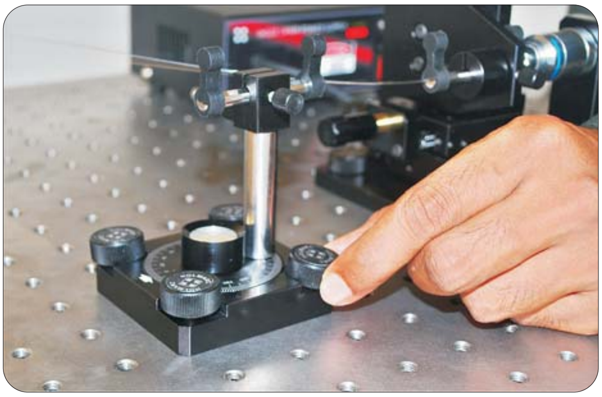
2. Fix one end of the optical fiber on the fiber chuck and mount it on the multi axis translation stage of the laser fiber coupler.





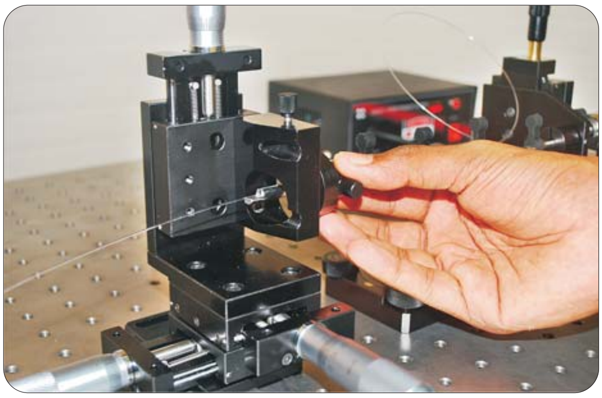


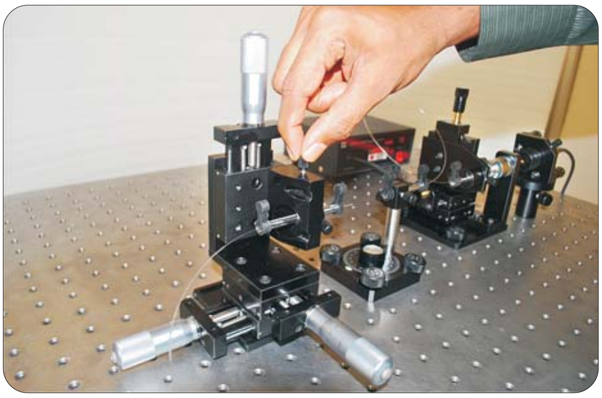
3. Using thumb screws fix the rotation stage properly on the breadboard and fix the fiber on to it.



4. Take another piece of fiber and fix it on the fiber chuck.

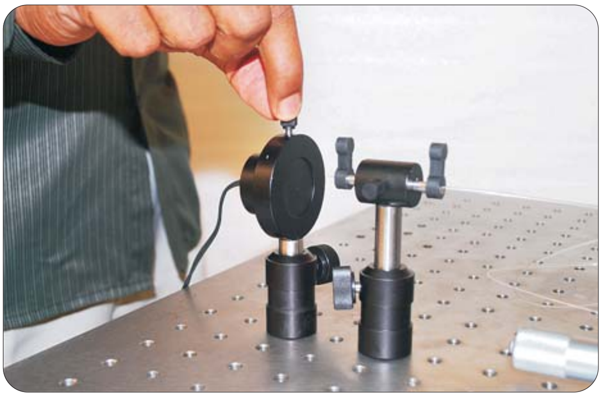
5. Insert the chuck in the cell mount of the XYZ translation stage. The fiber end fixed on the rotation stage and the receiving fiber end on the XYZ translation stage must be very close to each other.





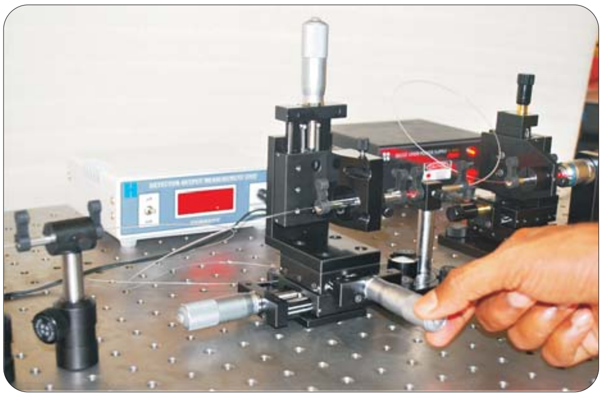
6. Fix the fiber chuck holder on the breadboard and mount the other end of the receiving fiber.

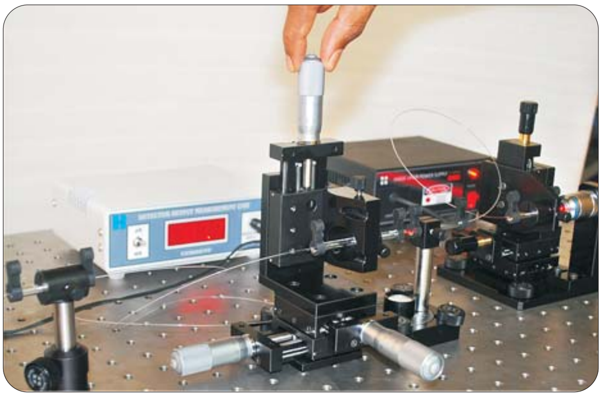
7. Place the cell mount and insert the pinhole photo detector.

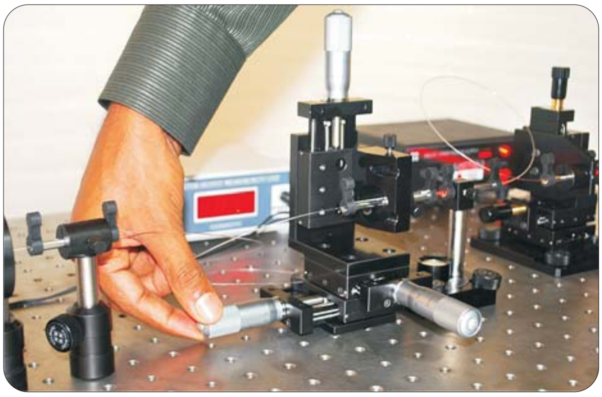


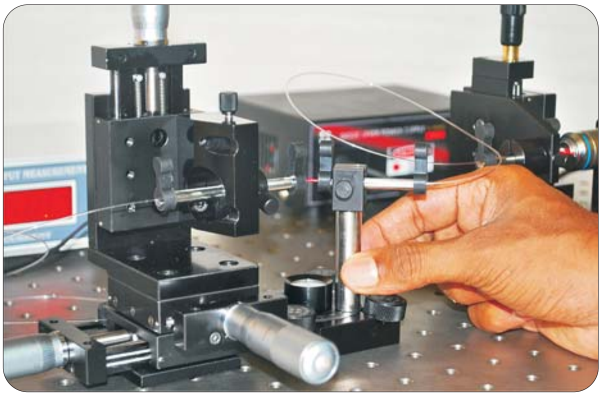
Procedure :

1. Switch on the diode laser and using the XYZ translation stage, laser fiber coupler and the tilt feature on the rotation stage obtain maximum output in the o/p measurement unit.
2. To study the loss due to misalignments caused in fiber, gradually move the receiving fiber end in longitudinal and transverse directions using the corresponding micrometers and note their outputs and also the micrometer readings. To study the loss due to angular misalignment, turn the rotation stage by small angles and note the corresponding readings.









3. Now, plot the necessary graphs.

Measurements :

Transverse offset:

Sl No:	Micrometer reading	Output current from the detector

Longitudinal offset:

Sl No:	Micrometer reading	Output current from the detector

Angular Offset:

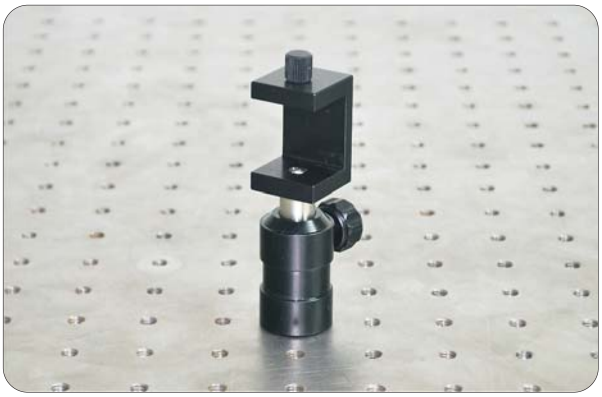
Sl No:	Angle turned	Output current from the detector

Result :

Made comparative study of loss tolerance to various offsets between two fibers at a joint.

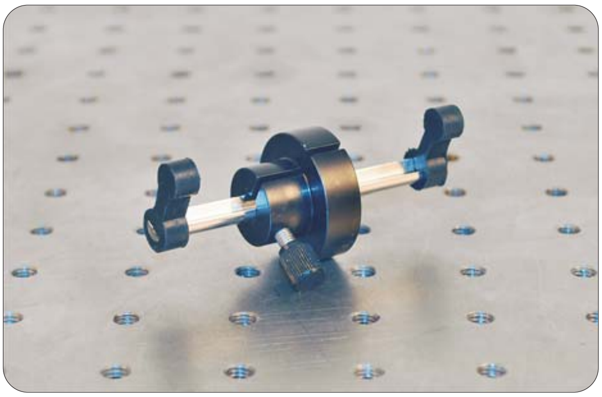
Observed that splice loss is most sensitive to transverse misalignments.

4. **PMMA Mount**



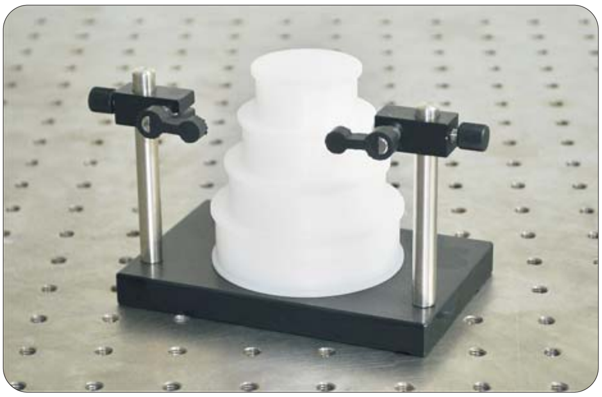
5. **Fiber Chuck holder**

6. **Fiber Chuck**



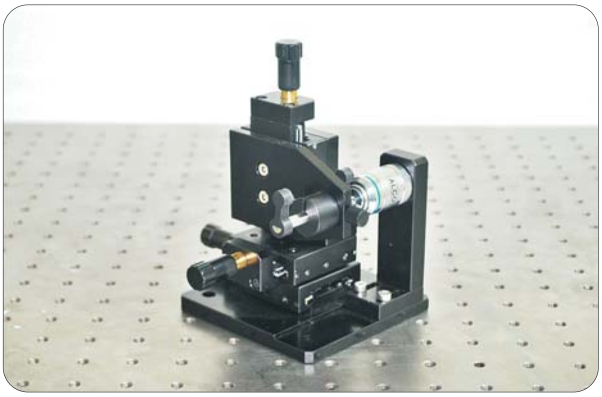
7. Bending Loss Apparatus

Diameters : 65mm, 55mm,
45mm & 35mm



8. Laser Fiber Coupler with multi translation stage

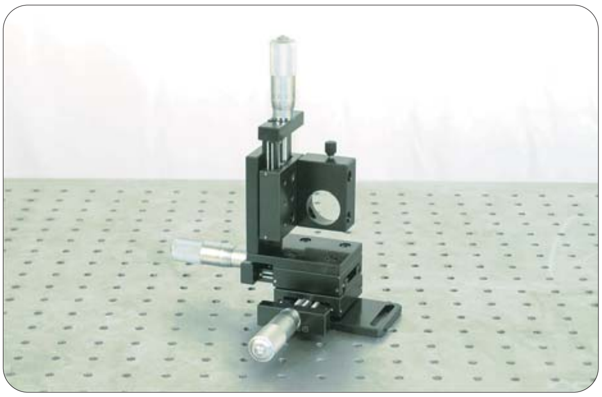
Microscope objective : 45X / 40X



9. XYZ Translation stage

25mm travel in X, Y & Z directions

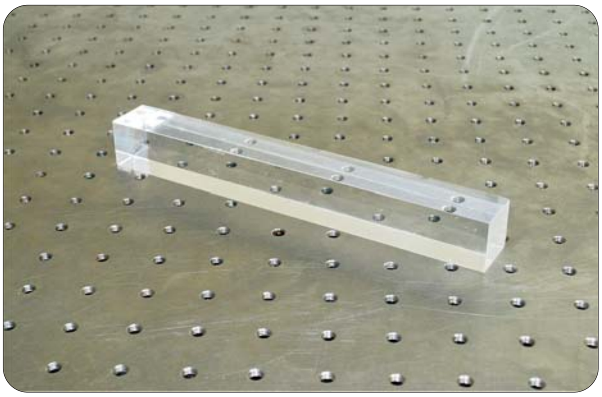
Least count of the micrometer : 0.01mm



10. PMMA ROD

Dimensions : 20 cm X 2.5 cm X 2.5 cm

Refractive Index : 1.5



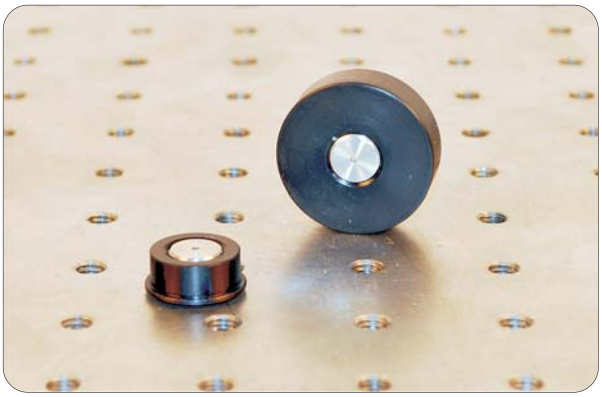
11. Diode Laser with Power supply

Input .... 230V AC / 50 Hz
Output power 5mW
Wavelength 650nm

12. Pinhole Photo detector with O/P measurement unit

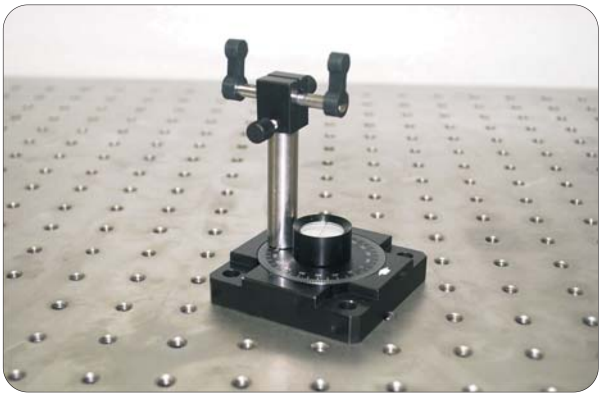
Input .... 230V AC / 50 Hz
Detector Type .... Photo transistor
Pinhole Diameter .... 0.7 mm
Range .... 0.0 - 200 μA &
0.0 - 200 mA

13. FC Connector Adapter



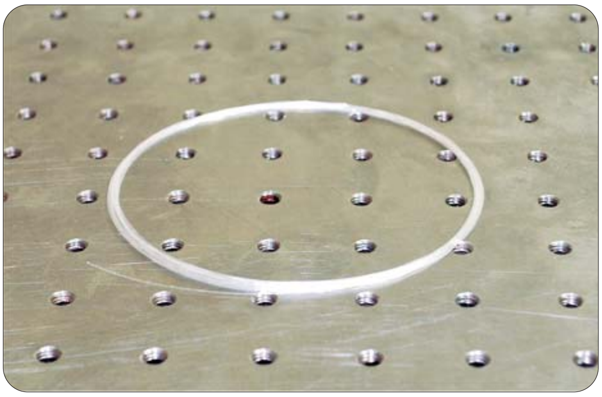
14. Rotation stage with fiber chuck

Rotation .... 0 - 360º
Resolution 2º



15. Thumb Screws

16. Multimode fibers



Type 1: End - point plastic fiber
OD - 250µm
Core - 240 µm
Attenuation - 0.35db/m
NA - 0.50
Temp rating of - 55 ~+70
Refractive index core = 1.492
Refractive index cladding = 1.402
Material of core - PMMA

Type 2: End - point plastic fiber
OD - 750µm
Core - 735 µm
Attenuation - 0.20db/m
NA - 0.50
Temp rating of - 55 ~+70
Refractive index core = 1.492
Refractive index cladding = 1.402
Material of core - PMMA

17. Single Mode Fiber

Numerical Aperture : 0.11± 0.015
Core diameter : 9 µm
V number @ 1550nm : 2.00
V number @ 650nm :4.70
Mode field diameter at 1550nm10.1 ± 0.8
Mode field diameter at 650 nm
0.13mm @1mm
Group refractive
index @1310nm : 1.4660 - 1.4677
Polarization Mode Dispersion (PMD) (ps/ √km) ≤ 0.2
External diameter (uncolored) µm 242 ± 8
Fiber curl radius m ≥ 4
Fiber Temperature dependence : -60ºC to +85ºC dB / km ≤ 0.05