EEP3010

Communication Systems Lab

Study of total internal reflection and Multimode mode Fiber Characterization

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Abstract:

In this experiment, we focus on the characterization of multimode fibers and determination of the refractive index of PMMA rod. This experiment explore the phenomenon of total internal reflection, refractive index of PMMA rod and its application in optical communication system. We also study the characterization of multimode fibers while calculating the numerical aperture, bending losses and the splice losses. It involves setting up a laser system with a kinematic mount, a diode laser and a PMMA rod. With the help of snell's law , we calculate the refractive index of the PMMA rod. The result of this experiment involves the understanding of optical properties of the material involved and designing efficient and reliable communication networks using precise measurements and theoretical principles such as snell's law. We observed the splice losses in translation , longitudinal and angular offset.

Objective:

The objective of this experiment is to understand the characterization of multimode fibers and determine the refractive index of PMMA rod, numerical aperture of these fibers, impact of bending on signal losses and losses that occur during splicing. In the experiment , we calculate the refractive index of the PMMA rod using the principle of total internal reflection.

Experimental Procedure:

Calculation of refractive index of PMMA Rod: In this we determine the refractive index of PMMA rod using total internal reflection.

The equipment required for this are:

- Kinematic Laser Mount
- Diode Laser
- Power Supply for Laser
- Mount for PMMA Rod
- PMMA Rod

In this we place the Kinematic Laser Mount on the breadboard and securely mount the diode laser. Then, mount the PMMA rod on the optical breadboard.

The procedure for this part of experiment is:

- Align the laser beam parallel to the PMMA rod.
- Rotate the laser to achieve the desired angle for total internal reflection.
- Now , record the incident angles using the dial on the laser mount and measure distance with meter scale.
- Then , we measure the distance a and b as shown in figure,
- Then using Snell's law and calculate the refractive index.
- Do the same procedure for different angles of incidence and calculate mean refractive index.

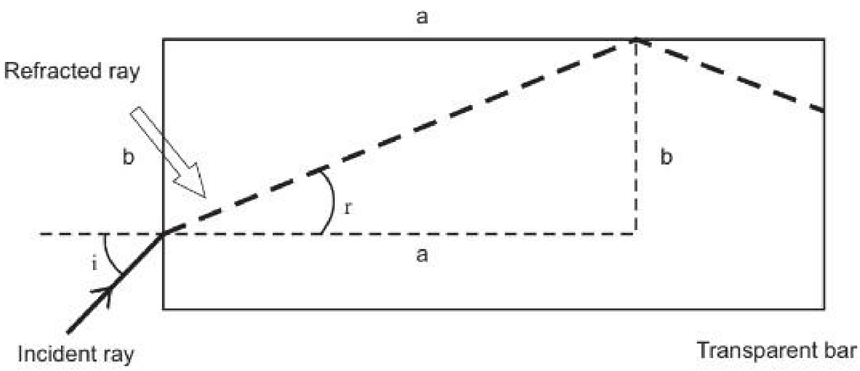


Figure (1)

As per Snell's law: n = sin i/ sin r where i is angle of incidence and r is angle of refraction.

Multimode Fiber Characterization: In this we determine the numerical aperture and calculate splice losses for translation , longitudinal and angular between fiber ends.

The equipment required for this are:

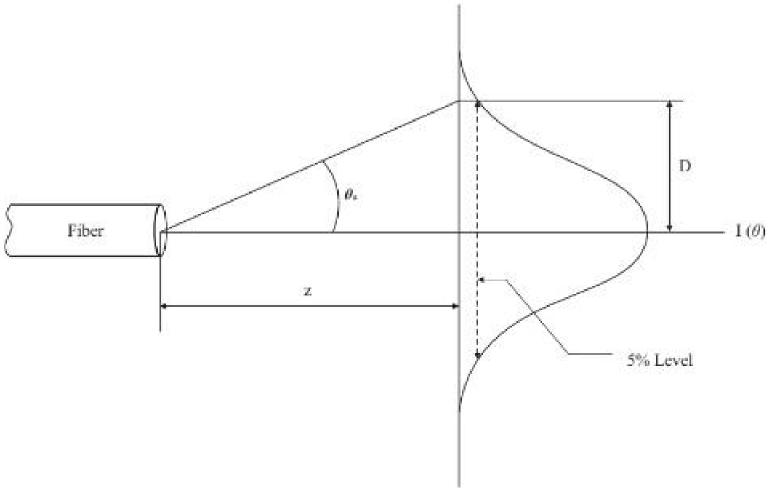
- Optical Breadboard with Rigid support
- Kinematic Laser Mount
- Bending loss apparatus
- Diode laser with power supply
- Laser-fiber Coupler with Multi-axis translation stage
- XYZ translation stage
- Pinhole detector with output measurement unit

1. **Numerical Aperture Determination:** 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, . θa
   In this we first ensure the experimental setup with optical breadboard , Kinematic laser Mount ,Diode laser and pin hole detector in their place .Then fix the fiber chuck holder on the breadboard. Then , we mount the fiber on the fiber chuck and insert it into the laser fiber coupler. After that we set up the XYZ translation stage and place the pinhole detector at the appropriate position.

The procedure for this part of experiment is:

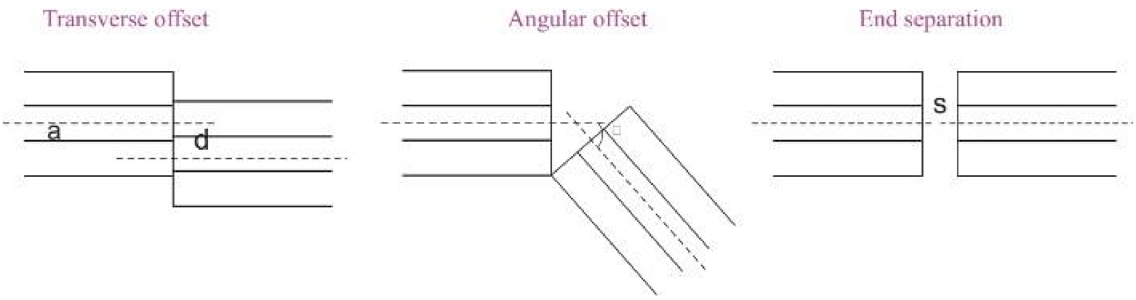
- First , switch on the diode laser and align the system to achieve maximum output current in the pinhole detector.
- Then using the XYZ translation stage to adjust the position of the fiber tip for optimal light coupling.
- Take the measurement of the micrometer readings and the corresponding output current.

- Measure the far-field intensity diameter (D) and the distance between the detector and the fiber output end (Z).
- Calculate the Numerical Aperture (NA) using the formula: NA = sin^(-1)(D/Z).



2.Splice loss calculation:

In this we keep the existing set up from the numerical aperture experiment. Optical power loss at the splicing point of two ends of optical fiber is known as splice loss.



The procedure for this part of experiment is:

- **Translation Alignment:** Use the XYZ translation stage to adjust the position of the receiving fiber end in the transverse direction. Now, record micrometer readings and the corresponding output current for each adjustment. Then ,calculate splice losses for different transverse misalignments.
- **Longitudinal Alignment:** Firstly, move the fiber chuck in the longitudinal direction using the micrometer. Then, record micrometer readings and output current for each longitudinal adjustment. Finally , calculate splice losses for different
  longitudinal misalignments.
- **Angular Alignment:** Firstly, use the Rotation Stage to introduce angular misalignments between the two fiber ends. Then, record the angle turned and

the corresponding output current. Finally, calculate splice losses for different angular misalignments.

Test Results:

1.Refractive index of PMMA rod:

Trial No.	Angle of Incidence(i)	a (cm)	b(cm)	r =Tan-1 (b/a)	Sin r	Sin i	n = sin i/sin r
1	42	0.6	0.4	33.69	0.554	0.399	1.39
2	43	1.5	1	33.69	0.554	0.391	1.417
3	44	3	1.5	26.56	0.447	0.331	1.35
4	41	4.5	2.4	28.07	0.470	0.313	1.501
5	45	5.4	2.6	25.70	0.473	0.31	1.48

Mean refractive index n = (1.39 + 1.417 + 1.35 + 1.501 + 1.48)/5 = 1.43 .

So, we calculate the refractive index of solid n = 1.43 .

2.Numerical Aperture :

Least count for the micrometer = 0.01 mm.

Serial No.	Micrometer Reading (mm)	Detector o/p current
1	0.51	0.1 micro ampere

From the graph we discussed earlier,

Diameter of far field intensity at 5 % intensity level of the maximum attainable intensity , D=0.51 mm .

Distance between the detector and the fiber output end , Z = 2 mm.

Acceptance angle , θa = tan -1(0.51 / 2) = 14.30 degree.

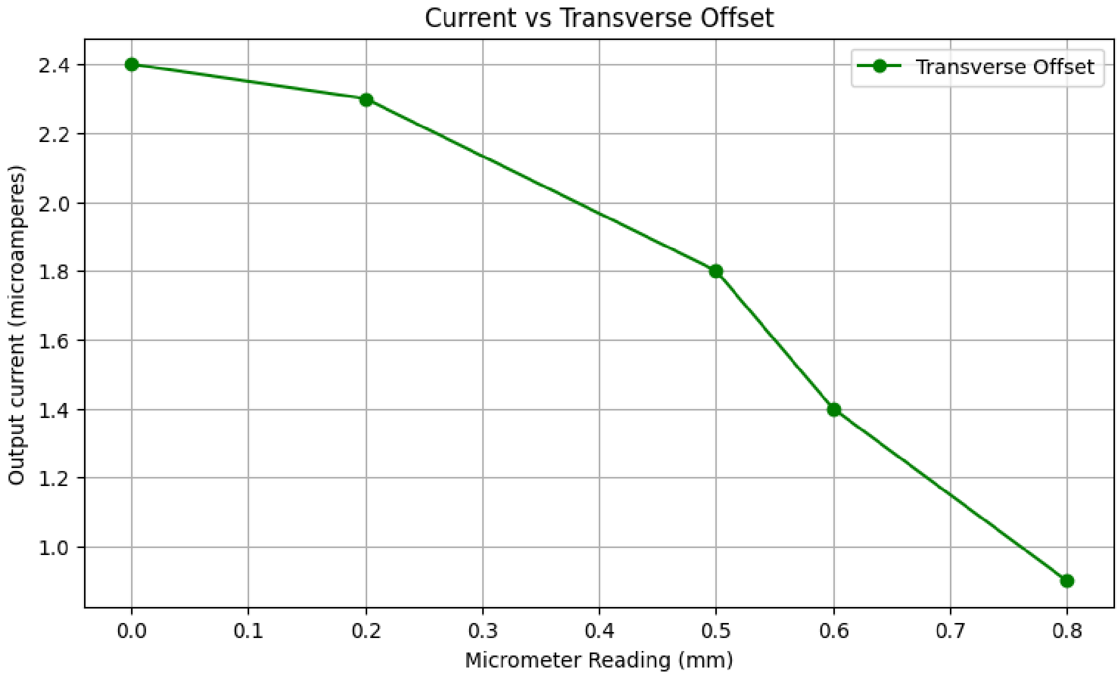
Then the numerical aperture is = NA = sin θa = 0.247 .

So, the numerical aperture of the given optical fiber , NA = 0.247 .

3.Splice Loss:

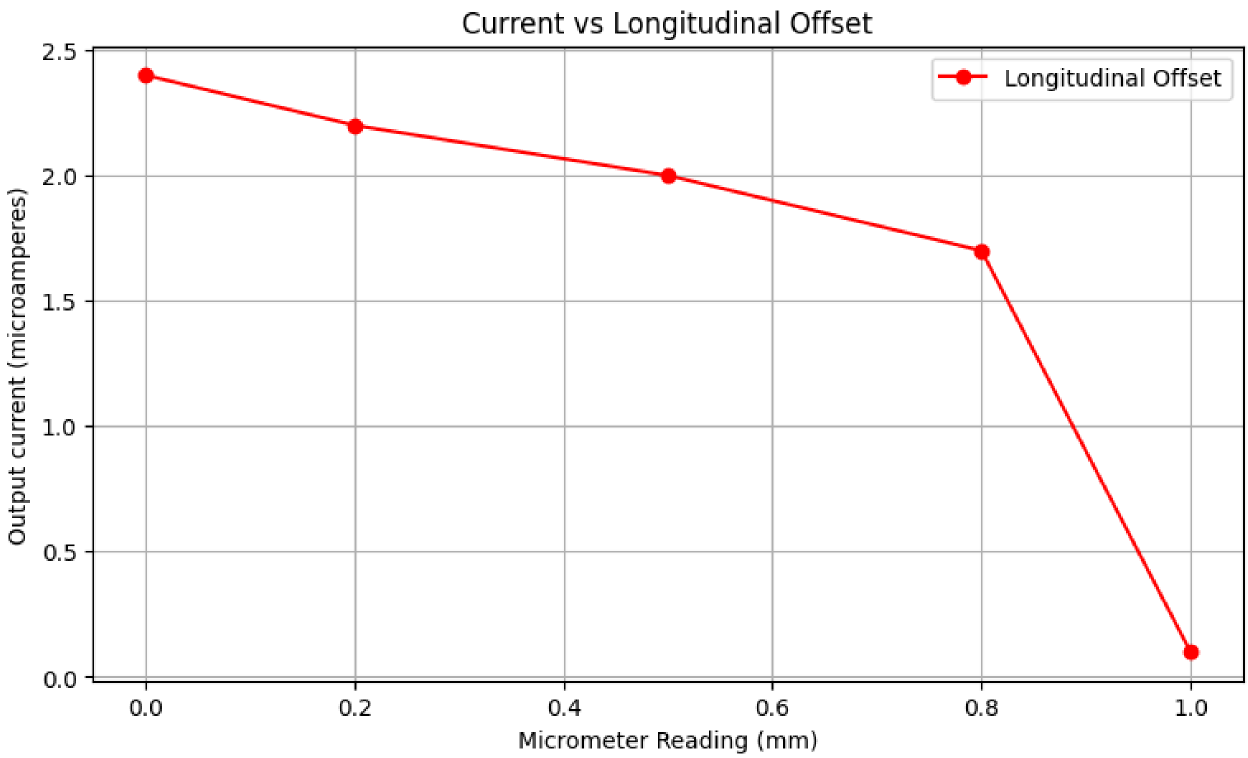
- **Transverse offset:**

Serial No.	Micrometer Reading	Output current from the detector
1	0 mm	2.4 microampere
2	0.2 mm	2.3 microampere
3	0.5 mm	1.8 microampere
4	0.6 mm	1.4 microampere
5	0.8 mm	0.9 microampere



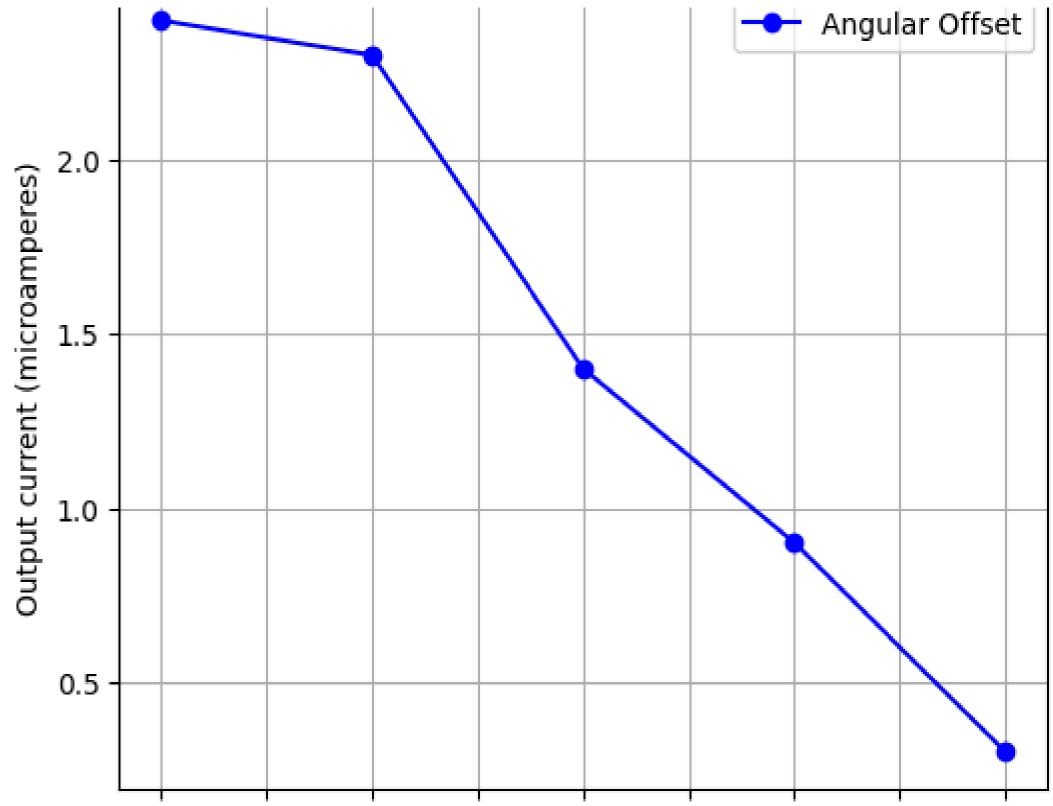
- **<u>Longitudinal Offset:</u>**

Serial No.	Micrometer Reading	Output current from the detector
1	0 mm	2.4 microampere
2	0.2 mm	2.2 microampere
3	0.5mm	2 microampere
4	0.8 mm	1.7 microampere
5	1 mm	0.1 microampere



- **<u>Angular offset:</u>**

Serial No.	Angle turned	Output current from the detector
1	0'	2.4 microampere
2	1'	2.3 microampere
3	2'	1.4 microampere
4	3'	0.9 microampere
5	4'	0.3 microampere



<u>Discussion:</u>

- Total internal reflection is when a light ray traversing a denser medium encounters the interface with a less dense medium at an angle surpassing the critical angle. At this boundary, a portion of the light reflects back into the denser medium, while the remaining is refracted into the less dense medium. If the angle of incidence surpasses the critical angle, all light is entirely reflected back into the denser medium, resulting in total internal reflection. In our experiment with the PMMA rod, we observed and quantified this phenomenon by calculating its refractive index . We use Snell's law to calculate the refractive index using n = sin i /sin r.
- The numerical aperture of the fiber was determined by adjusting the output current to 5% of its maximum value, which was observed to be 0.9 mA. As the photo detector deviated from the normal, a reduction in the output current was observed, indicating a point where light ceased to enter the fiber. This delineates a cone, and the corresponding angle within it is termed the acceptance angle, crucial for calculating the numerical aperture.

- Increasing offset values were associated with a decline in photodetector current, indicating splice loss in translation, longitudinal and angular.

Conclusions:

- In the experiment , we observed that PMMA rods observe total internal reflection (i.e Snell's law) and calculate the refractive index of the rod.
- In this we calculate the acceptance angle and numerical aperture for the optical Fiber.
- In this we observed three types of splice losses occurred due to Transverse offset, longitudinal offset and angular offset and graphs were plotted with effect.

References:

- Lab Manual For Experiment #9.
- Principles of communication systems – S .Haykin .
- Communication system Notes