

EXPERIMENT No. -----

Aim: - To Determine Numerical Aperture of Optical Fibre.

Practical Significance: - The **Determination of Numerical Aperture of Optical Fibre** experiment has significant practical importance because it helps students understand how efficiently an optical fibre can collect and transmit light. The Numerical Aperture (NA) is a key parameter that influences the performance of fibre optic communication systems and optical devices.

Numerical Aperture affects ease of coupling: a larger NA ensures easier coupling. Fibres with tailored NA are used for precise measurements in optical sensors. Ultimately, NA affects the fibre design and manufacturing cost, balancing transmission quality, minimizing loss, and optimizing efficiency.

Relevant Program Outcomes (POs):

1. **PO1: Engineering Knowledge-** Applies principles of optics and fibre optics to determine the Numerical Aperture of an optical fibre.
2. **PO2: Problem Analysis** - Analyzes experimental observations and calculates the Numerical Aperture using appropriate formulas.
3. **PO5: Modern Tool Usage-** Uses optical fibre kits, laser sources, and measuring instruments effectively.
4. **PO8: Ethics-** Demonstrates ethical laboratory practices by following safety precautions, handling optical equipment responsibly, recording observations honestly, and reporting accurate experimental results.
5. **PO9: Individual and Team Work-** Performs the experiment individually or collaboratively while maintaining coordination and responsibility.
6. **PO10: Communication-** Presents experimental procedures, calculations, observations, and conclusions clearly through the lab record and viva.
7. **PO12: Life-long Learning-** Develops curiosity and a continuous learning attitude toward fibre optics, photonics, and emerging optical communication technologies through practical experimentation.

Relevant Course Outcome: - Students will be able to understand the principles, significance, and applications of optical fibre and also the use of NA for specific applications like telecommunications, medical imaging, etc.

Practical Learning Outcomes (PLOs):

After successfully performing this experiment, the student will be able to:

1. Explain the concept of Numerical Aperture (NA) and its significance in optical fibres.
2. Set up and align the optical fibre experimental apparatus correctly.
3. Determine the acceptance angle parameters and the Numerical Aperture experimentally.
4. Apply the principles of Total Internal Reflection and Acceptance Angle to analyse light propagation in optical fibres.

Practical Skills Developed:

- ✓ **Optical Fibre Handling:** Learns to handle, align, and connect optical fibre components carefully without causing damage.
- ✓ **Precision Measurement:** Develops accuracy in measuring beam diameter and distance using laboratory instruments.
- ✓ **Experimental Setup:** Gains hands-on experience in setting up and operating the optical fibre and laser apparatus correctly.
- ✓ **Data Analysis:** Enhances skills in recording observations, performing calculations, and interpreting experimental results.
- ✓ **Reporting Skills:** Improves the ability to prepare well-organized laboratory records, present calculations clearly, and write accurate conclusions based on experimental observations.
- ✓ **Problem-Solving:** Identifies experimental errors and applies corrective measures to improve measurement accuracy.
- ✓ **Laboratory Safety:** Follows safe laboratory practices while handling laser sources and delicate optical equipment.

Relevant Affective Domain Related Outcomes (RADOs):

1. **Receiving:** Pays attention to laboratory instructions, safety precautions, and demonstration of the experimental setup.
2. **Responding:** Actively participates in conducting the experiment and follows the prescribed procedure.
3. **Valuing:** Appreciates the importance of accuracy, precision, ethical data recording, and careful handling of optical equipment.
4. **Organization:** Integrates scientific attitude, teamwork, laboratory safety, and ethical practices while performing the experiment.
5. **Characterization:** Demonstrates responsibility, professionalism, and consistent adherence to good laboratory practices during experimentation.

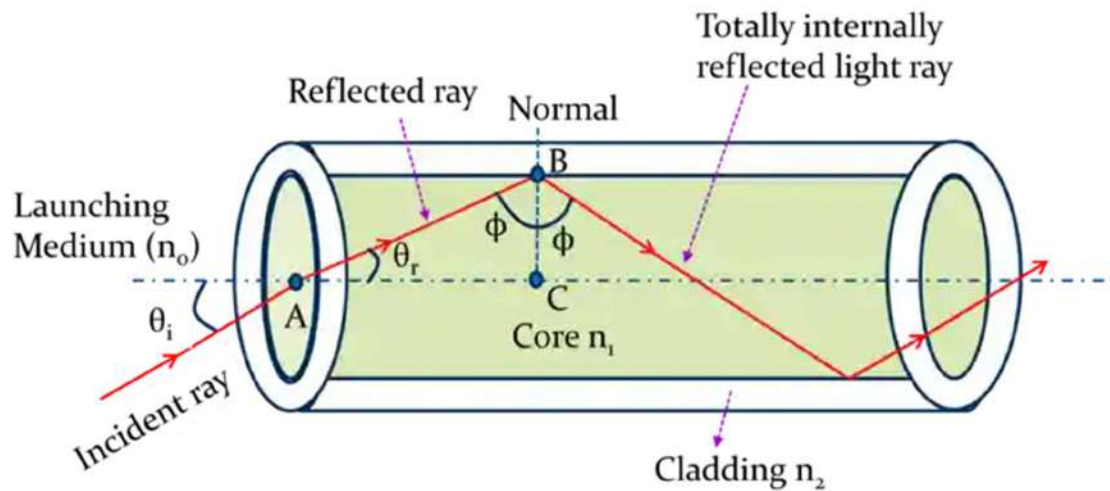
Here **Receiving, Responding, and Valuing** are the most strongly achieved through a single laboratory experiment, while **Organization** and **Characterization** are developed progressively across multiple laboratory sessions.

Theoretical Background:

The Numerical Aperture (NA) of an optical fibre is a measure of its light-gathering ability. A fibre with a higher Numerical Aperture can accept light over a larger range of angles, making light coupling from a laser or LED easier and more efficient.

The propagation of light inside an optical fibre is based on the principle of Total Internal Reflection (TIR). When light enters the fibre within a certain maximum angle, called the acceptance angle (θ_a), it undergoes repeated total internal reflections at the core-cladding interface and travels through the fibre with very

little loss. If the light enters at an angle greater than the acceptance angle, it escapes into the cladding and is not guided.



For an optical fibre placed in air, the Numerical Aperture is given by:

$$NA = \sin \theta_{\max}$$

Where $\theta_{\max}$ is acceptance angle.

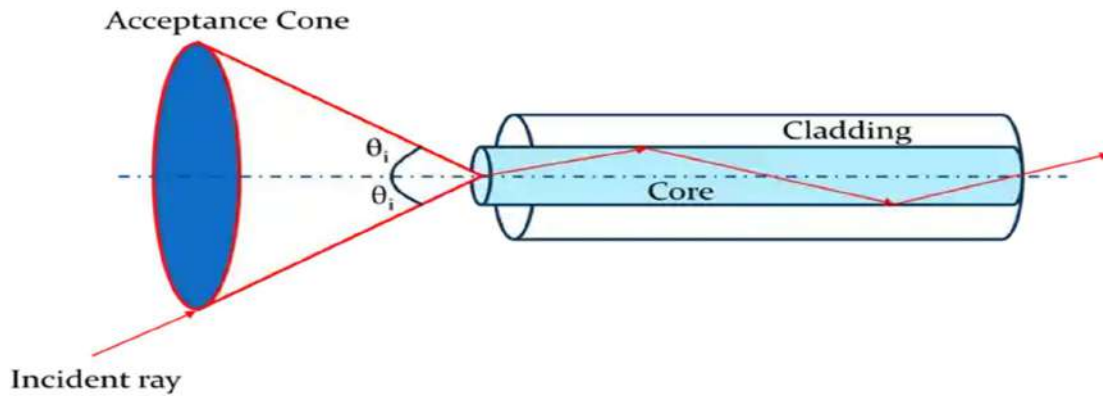
The Numerical Aperture can also be expressed in terms of the refractive indices of the core and cladding:

$$NA = \sqrt{n_1^2 - n_2^2}$$

where:

- n_1 = Refractive index of the core
- n_2 = Refractive index of the cladding

The acceptance angle forms an imaginary cone called the **acceptance cone**. Any light ray entering within this cone will propagate through the fibre with minimal loss, whereas rays entering outside the cone are rejected.



During the laboratory experiment, this acceptance cone is observed indirectly by allowing light to emerge from the other end of the fibre. As the light exits, it spreads into a circular spot whose diameter depends upon the numerical aperture of the fibre.

By measuring the spot diameter and the distance between the fibre end and the screen, the acceptance angle can be calculated using simple trigonometry.

The relationship between these quantities is given by

$$\tan \theta = \frac{D}{2d}$$

where:

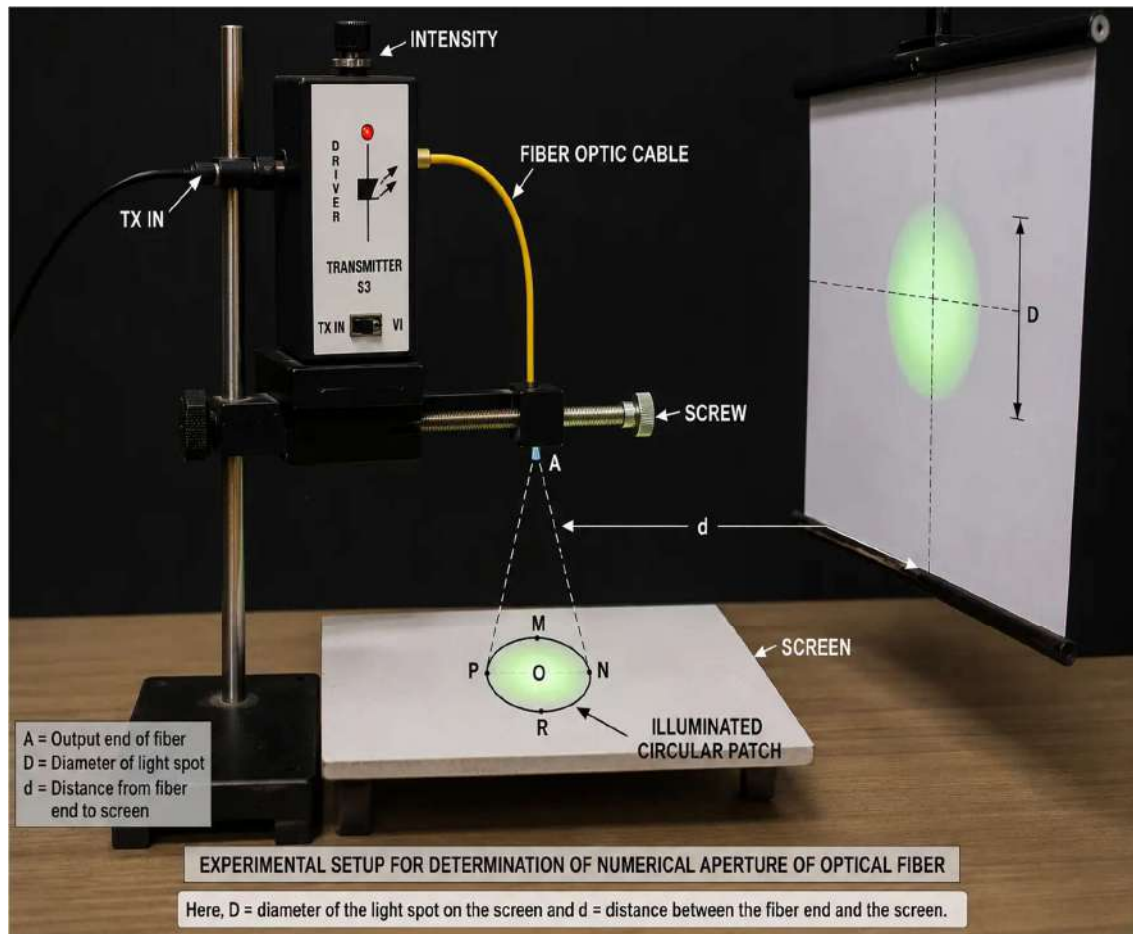
- **D** = Diameter of the light spot on the screen
- **d** = Distance between the fibre end and the screen

By combining geometry and optics, the practical expression often used in laboratories becomes

$$NA = \frac{D}{\sqrt{4d^2 + D^2}}$$

IF r is the radius of the spot, then $NA = \frac{r}{\sqrt{r^2 + d^2}}$

Experimental Setup:



Resources Required:

S. No.	Name of Equipment	Specifications	Required Quantity	Remark
1	Laser source (or LED source)	with fibre-coupling mount	1	
2	Step-index optical fibre patch cord	both ends polished	1	
3	Numerical aperture measurement jig	with a graph-ruled screen	1	
4	Measuring scale	-	1	
5	Fibre-holding clamp	-	1	

Precautions:

1. **Handle the optical fibre carefully** and avoid sharp bending, as it may damage the fibre and affect the results.
2. **Clean the fibre end faces** to remove dust or dirt, which can reduce light transmission.
3. **Measure the distance (d)** between the fibre end and the screen accurately without parallax error.
4. **Measure the diameter (D)** of the light spot carefully through its centre for accurate calculations.
5. **Keep the screen perpendicular** to the emerging light beam to obtain a circular spot.
6. **Take multiple observations** and use the average values to minimize experimental errors.
7. **Switch off the power supply** after completing the experiment and handle the equipment safely.

Experimental Procedure:

1. Connect the optical fibre to the transmitter unit and switch on the power supply.
2. Adjust the intensity control to obtain a bright and uniform light output from the fibre.
3. Fix the output end of the optical fibre vertically using the holder provided in the experimental setup.
4. Ensure proper alignment so that the light emerging from the fibre falls normally on the screen and forms a clear circular spot.
5. Measure the distance (d) between the output end of the fibre and the screen using a scale.
6. Measure the diameter (D) of the illuminated circular spot on the screen in two mutually perpendicular directions and calculate the average diameter.
7. The radius of the light spot was calculated as: $r = D / 2$ (or using $r = (MR + PN) / 4$ for crossed directions).
8. Repeat the observations for two or three different values of d by changing distance between the output end of the fibre and the screen.

9. Calculate the Numerical Aperture (NA) for each observation using the formula:

$$NA = \frac{r}{\sqrt{r^2 + d^2}}$$

10. Determine the average value of the Numerical Aperture.

11. Switch off the power supply and disconnect the apparatus after completing the experiment.

Observation Table:

S. No.	Distance d (cm)	Diameter of the Spot		Radius $r = \frac{PN+}{4}$ (cm)	$NA = \frac{r}{\sqrt{r^2 + d^2}}$
		Along one direction (PN)	Along perpendicular direction (MR)		
1					
2					
3					

Calculation:

Average NA =

Result:

The Numerical Aperture of the given optical fibre is

Conclusion: The numerical aperture of the given optical fibre was calculated successfully. The experiment verified the principle of light propagation in optical fibres and helped in understanding the importance of numerical aperture in fibre-optic communication.

Recommendations:

- Measurements should be repeated several times, and the average value should be used to minimize experimental errors.
- The observation screen should be positioned accurately, and distances should be measured carefully using calibrated instruments.