# INSTRUCTIONAL SHEET

## FIBER OPTIC APPARATUS - NA Measurements


# Applied Science Department

# NITTTR, Sector-26, Chandigarh

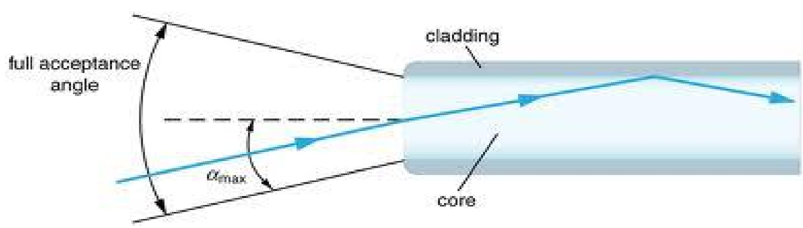
# Fiber Optic Apparatus: NA Measurements

**Objective :** To measure the numerical aperture (NA) of an optical fiber with the help of Fiber Optic Apparatus and hence to deduce V-number for the optical fiber.

**Apparatus:** Diode Laser Source, Photodetector, Multimeter, Microscope Objective, Fiber Holders (2 nos.), Optical Fibers, Base with rotational mount, Holders and Bases.

**Theory:**

Optical fiber is one of the important elements in an optical fiber link. The performance of the link depends upon the attenuation and dispersion properties of optical fiber, which in turn are function of the input power carried by the cabled fiber. Considered propagation of light in an optical fiber, the condition of total internal reflection at the core-cladding interface is necessary. Therefore, for rays to be transmitted by total internal reflection within the fiber core they must be incident on the fiber core within an acceptance cone defined by the conical half angle ($\alpha_{max}$). Thus, $\alpha_{max}$ is the maximum angle to the axis at which light may enter the fiber in order to be propagated and is often referred to as the acceptance angle for the fiber.




**Light Propagation through optical fiber**

A more generally used term, the numerical aperture relates the acceptance angle and refractive indices of the three media involved (the core, cladding and air) and is a basic descriptive characteristic of a specific optical fiber. It represents the size or degree of openness of the input acceptance cone. Mathematically it is defined as the sine half angle of the acceptance cone and is a very useful measure of light-collecting ability of a fiber.

Using Snellôs law, the maximum angle within which light will be accepted into and guided through optical fiber is

$$NA = n_0 \, Sin\,(\alpha_{max}) = (n_1^2 - n_2^2)^{1/2}$$

where $\alpha_{max}$ is the half acceptance angle, $n_0$ the refractive index of air and $n_1$ and $n_2$ are the refractive indices of the core and the cladding respectively. If the incident angle $\alpha<\alpha_{max}$, the ray undergoes multiple internal reflections at core and cladding interface and it is called the guided ray. If $\alpha<\alpha_{max}$, the ray undergoes only partial reflection at core cladding interface.

In short length of straight fiber, ideally a ray launched at angle $\alpha$ at the input end should come out at the same angle $\alpha$ from output end. Therefore, the far field at the output end will also appear as a cone of semi angle $\alpha_{max}$ emanating from the fiber end.

**Experiment No. 1 : Numerical Aperture of Plastic Fiber**

**Experimental Setup**

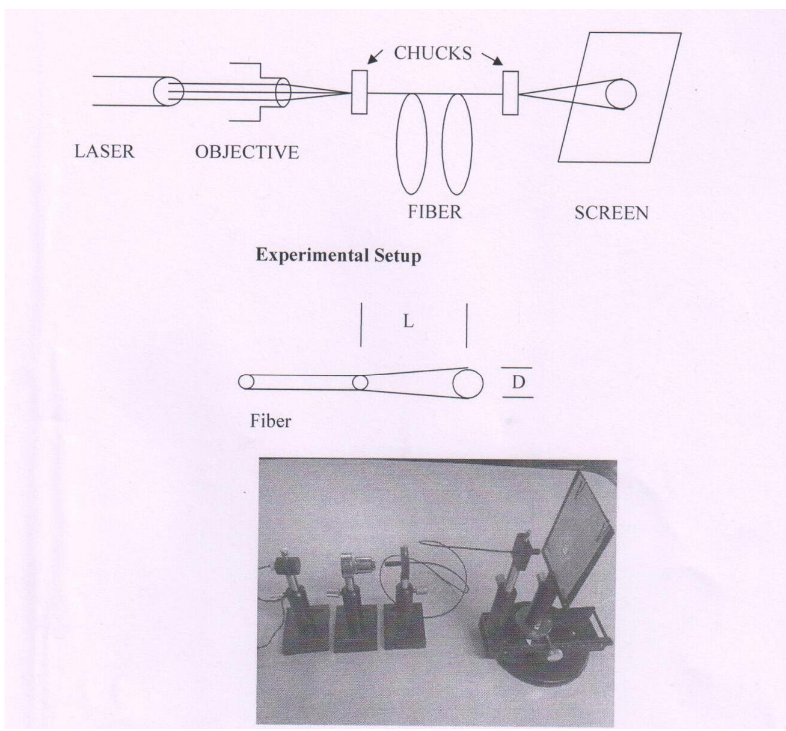



**Fig. 1:** Experimental setup for NA measurements

**Procedure:**

1. Mount Laser source, objective and screen on the respective holders as shown in Fig.1.
2. Mount both the ends of the optical fiber on the fiber holders.
3. Align the different objects as per the setup shown in figure.

4. Couple the light from the laser source onto one of the fiber ends using a microscopic objective (provided with the kit).
5. Place the screen (sheet having circular markings) at some distance from the output end of the fiber such that it is perpendicular to the axis of the fiber. Now move the screen towards or away from the output end of the fiber such that circular beam emanating from the fiber end covers the ($1^{st}$ or $2^{nd}$ or $3^{rd}$) circle on the screen.
6. Measure the distance between the output end of optical fiber and screen. Let this be L, also measure the diameter of the circular spot formed on the screen. (Diameters are mentioned in mm). Let it be D.
7. Use the formulaœs to calculate NA and V number for the fiber

$$NA = \sin \alpha_{max} = \sin\left[\mathbf{tan}^{-1}\left(\frac{D}{2L}\right)\right]$$

and

$$V = \frac{2\pi a}{\lambda}.NA$$

Where a is the radius of the fiber and $\lambda$ the wavelength of the light source.

**<u>Experiment No. 2</u> : Numerical Aperture for Glass Fibers**

**Experimental Setup:**

**Fig. 2:** Experimental setup for measurement of NA of glass fiber

**Procedure:**

1. Setup the experimental parts as per Fig.2. Light from the laser is coupled into the given optical fiber by using microscope objective.

2. Place the output end of the fiber on the rotating stage.
3. A photodetector, whose output is connected to the votlmeter, is mounted on the base and align it for maximum intensity (Vmax) such that the pinhole is at the same horizontal level as the fiber end. Connect the output of the detector to multimeter using wire provided with the apparatus having BNC socket at one end and banana plugs at other end (with red wire V+ socket and black wire to Com socket) and select Voltage mode.
4. Without disturbing the input coupling, rotate the output fiber end spot in suitable steps and at each angular position record the detector output.
5. Plot and extrapolate graph showing the output of detector vs. angular position.
6. From the graph, find out the angle $2\alpha_{max}$ corresponding to the 0.95 Vmax below from the maximum detector reading and hence obtain $\alpha_{max}$.
7. Find NA for the fiber and hence V-number using the relations.

$$NA = \sin(\alpha_{max}) \quad \text{and} \quad V = \frac{2\pi a}{\lambda} . NA$$

**Observation Table for NA**

| S.No. | Angular Deflection | Detector Reading |
|---|---|---|
| 1. | | |
| 2. | | |
| 3. | | |
| 4. | | |

**Result:**

NA of given optical fiber = 0.5 (multimode fiber), 0.2-0.3 (singlemode fiber).

**Precautions:**

1. Mounting and coupling should be carefully done.
2. Glass optical fibers are thin, delicate and should be handled carefully.
2. Care should be taken so that laser light should not directly fall into the eye.
3. As far as possible, experiment should be conducted in dark room environment.

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