Experiment - 2: Measurement of Numerical Aperture of Optical Fiber

Date: - 24/01/25

1. **Aim:** To measure the numerical aperture of the plastic fiber using 660 nm wavelength LED.

2. **Requirements:** Function Generator, CRO, Experimental Kit, 1 Meter Fiber Cable, Probes, Fiber holding fixture, Power Supply, Connecting links.

3. **Pre Experiment Exercise:**
   Brief Theory

One of the primary parameters of a fiber is its *Numerical Aperture*. This parameter is used in equations describing the coupling losses of the source light entering the fiber, connector and splice losses, and other system performance equations.

Consider a ray, internal to the fiber as shown above, that is incident on the core-cladding interface at exactly the critical angle. If we extend this ray back through the fiber-air interface at the input by applying Snell's law, it will have an angle of incidence given by *θmax*. All incident rays with angles less than *θmax* will have a core-cladding angle of incidence greater than the critical incident angle and will be guided down the fiber. All input rays with angles greater than *θmax* will intercept the core-cladding interface at an angle less than the critical incident angle, will be partially transmitted through the interface, and hence will suffer some loss at each reflection. They will soon be attenuated into insignificance if the fiber is relatively long.
The maximum angle *θmax* is given by:

$$\theta_{\max} = \sin^{-1}\left(\sqrt{n_1^2 - n_2^2}\right) \approx \sin^{-1}\left(n_1\sqrt{2\Delta}\right)$$

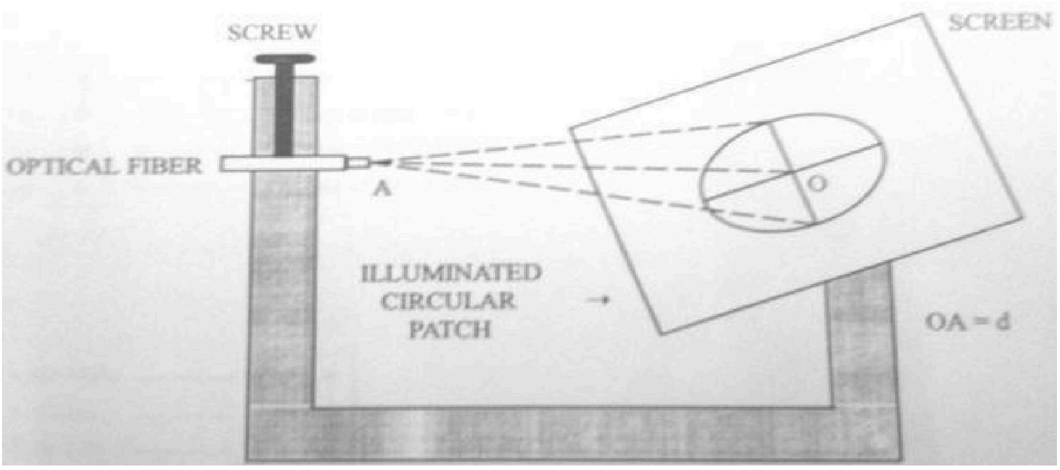
The Numerical Aperture of the fiber is the sine of this maximum input angle and is given by:

$$\mathrm{NA} = \sin\theta_{\max} = \sqrt{n_1^2 - n_2^2} \approx n_1\sqrt{2\Delta}$$

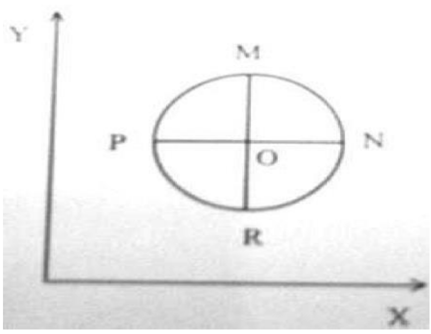
Considerations in NA measurement:

1. It is very important that the optical source should be properly aligned with the cable & the distance from the launched points and the cable be properly selected to ensure that the maximum amount of optical power is transferred to the cable.
2. This experiment is the best performed in a *less illuminated room*.

4. **Laboratory Exercise:**



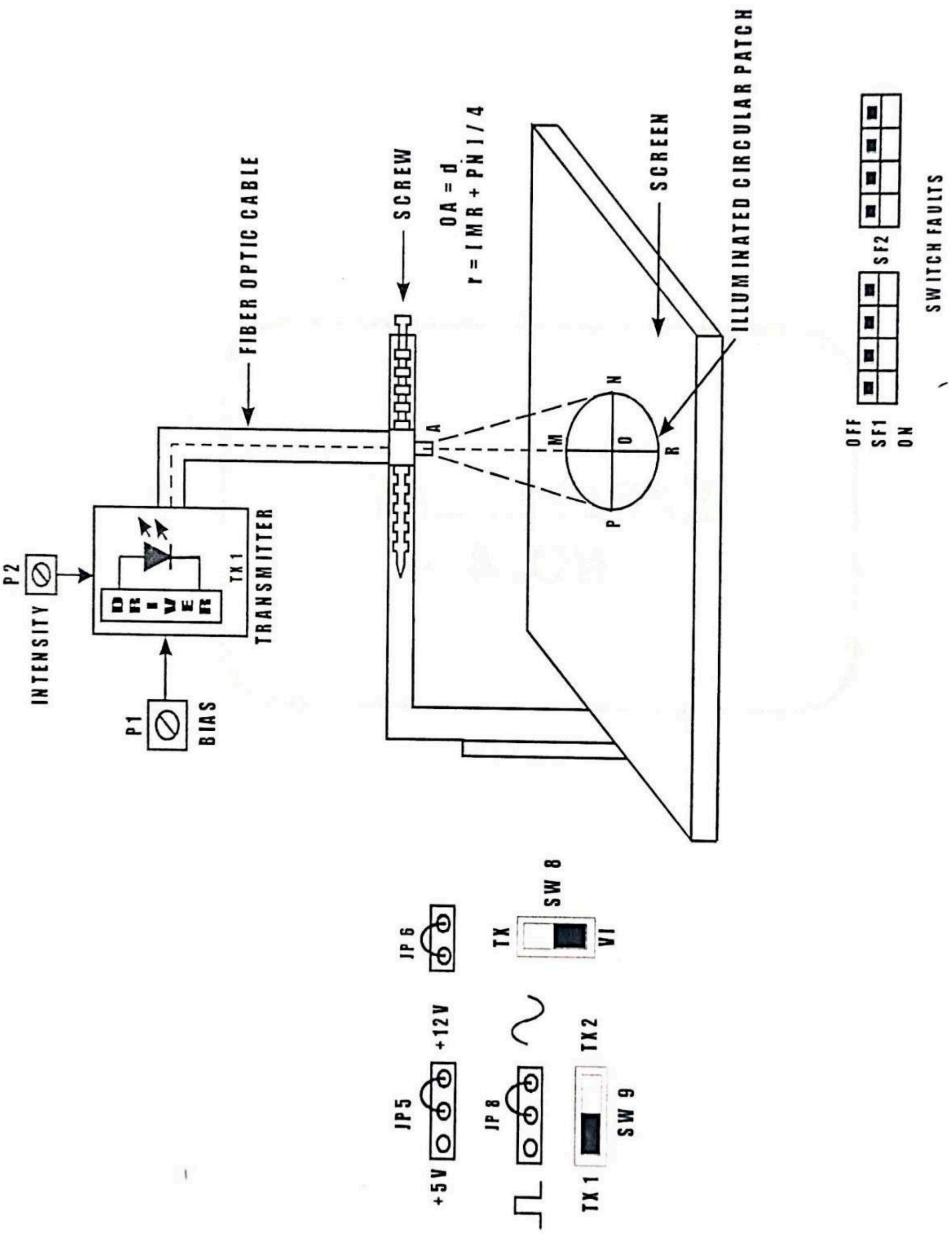
Setup for measurement of Numerical Aperture:



Procedure

1. Slightly unscrew the capo of LED SFH756V. Do not remove the cap from the connector.
2. Once the cap is loosened, insert the fiber into the cap. Now tighten the cap by screwing it back.
3. Connect the power cord to the kit & switch on the power supply. Apply TTL high input to the LED from EXT-TTL terminal.
4. Insert the other end of the fiber into the numerical aperture measurement jig. Hold the graph sheet facing the fiber in the place.
5. Now observe the illuminated circular patch of light on the screen (room should be less illuminated).
6. Measure exactly the distance d and also the vertical and horizontal diameter MR and PN as indicated in the figure.
7. Mean radius is calculated using the following formula $r = (MR + PN)/4$
8. Find the numerical aperture of the fiber using the formula

$$\mathrm{NA} = \sin\theta = \frac{r}{\sqrt{(r^2 + d^2)}}$$


FIBER OPTIC CABLE
SCREW
OA = d
r = [MR + PN] / 4
SCREEN
ILLUMINATED CIRCULAR PATCH
INTENSITY
P2
P1
BIAS
DRIVER
TX1
TRANSMITTER
A
M
N
O
P
R
OFF
SF1
ON
SF2
SWITCH FAULTS
JP5
+5V
+12V
JP6
JP8
TX
SW 8
VI
TX 1
SW 9
TX 2

Observations: Perform observations for values of d = 5mm, 10mm, 15mm and 20 mm

d (mm)	MR	PN	r = (MR + PN) / 4	NA	θ
5	5.5	5.5	2.75	0.4819	28.81
10	9.5	9.5	4.75	0.4290	25.40
15	14	14	7	0.4288	25.39

Average Numerical Aperture: **0.4465**

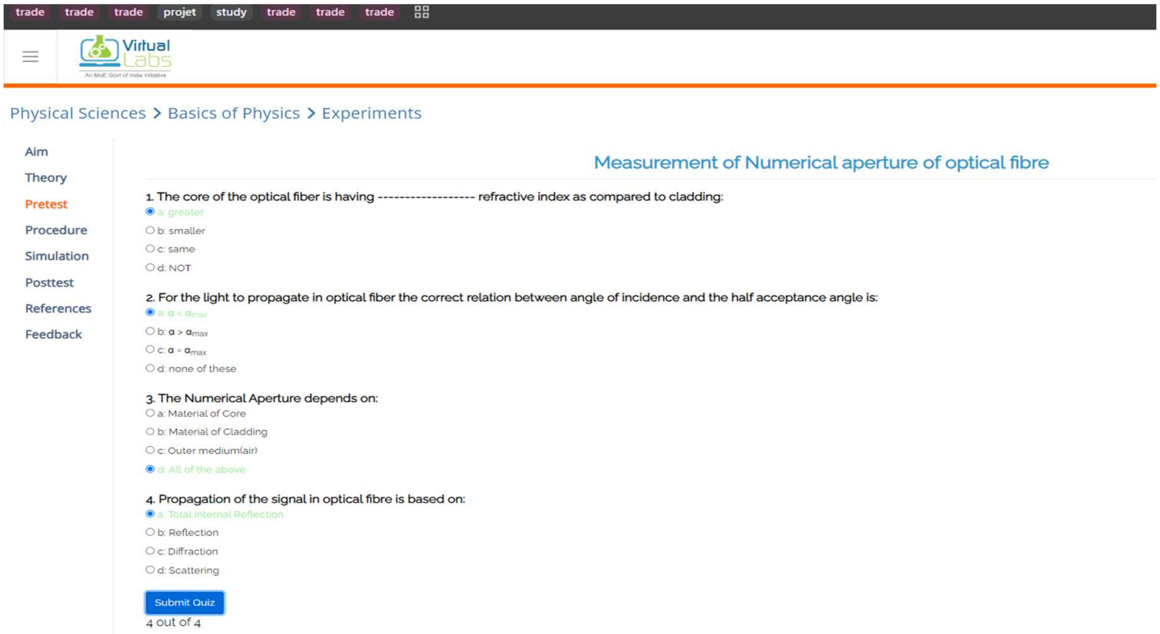
5. Conclusion/Comments:

6. Questions

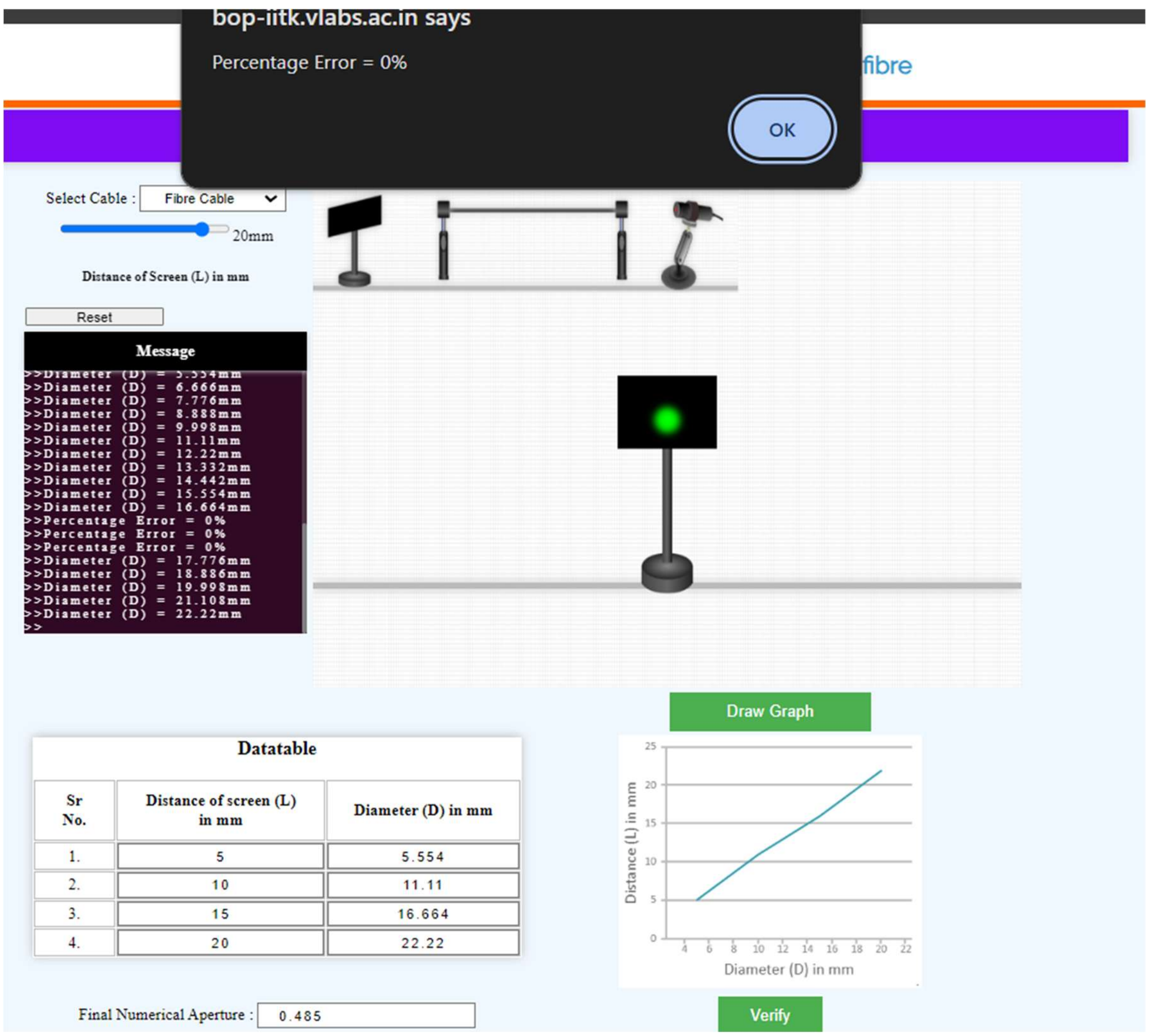
1. Find the core radius necessary for single mode operation at 1320 nm of a step index fiber with n1=1.480 and n2=1.478. What are the numerical aperture and maximum acceptance angle of this fiber?
2. Calculate the numerical apertures of (a) a plastic step-index fiber having a core refractive index of n1=1.60 and a cladding index of n2=1.49, (b) a step index fiber having a silica core (n1=1.458) and a silicone resin cladding (n2=1.405)
3. Explain the significance of the V- number.
4. Draw the refractive index profile of a graded index fiber and show with a neat diagram transmission of light through this fiber. Explain how GRIN fiber has transmission bit rate much higher than multitude Step index fiber.

OCN 2

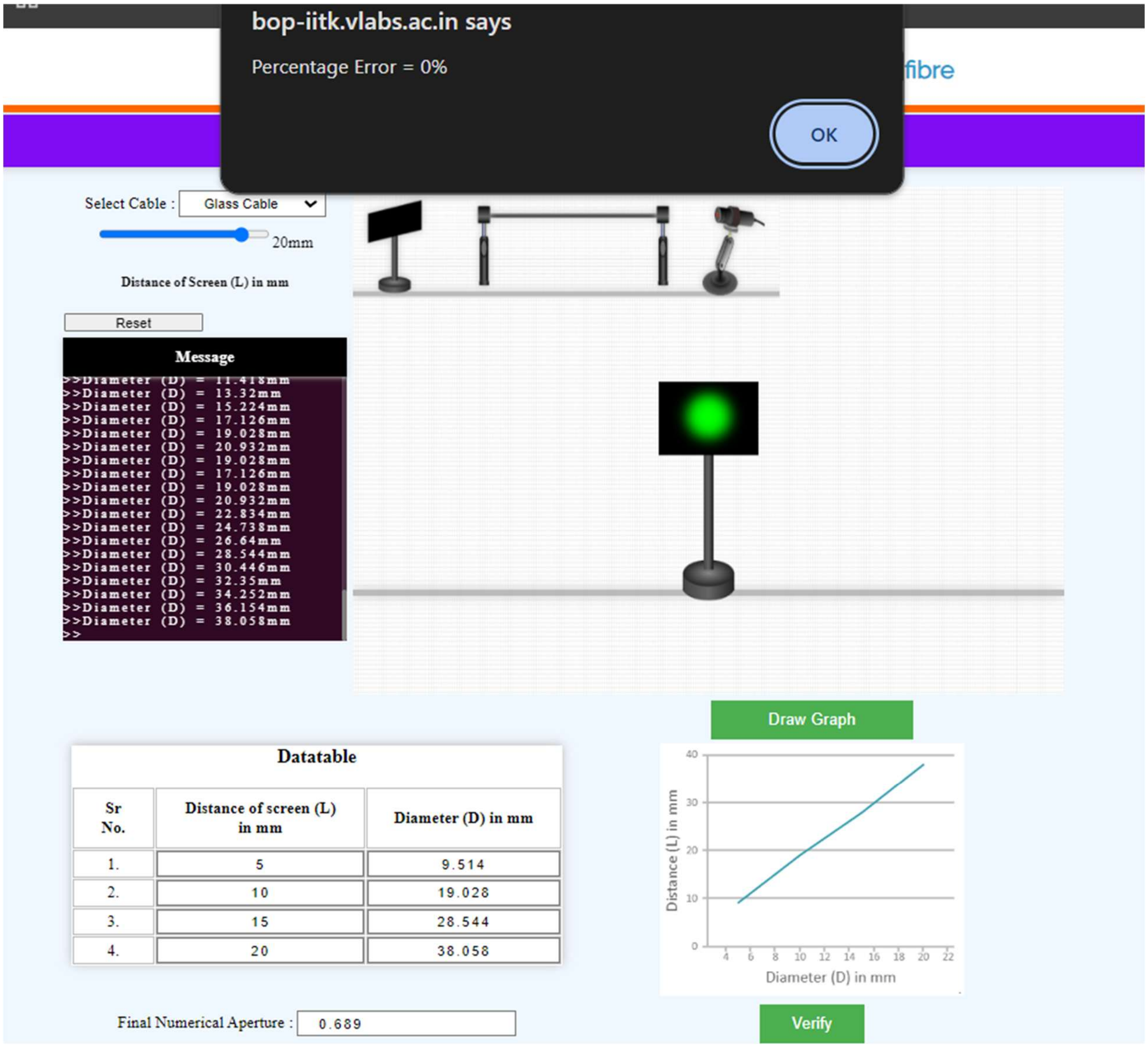
Pre-test:



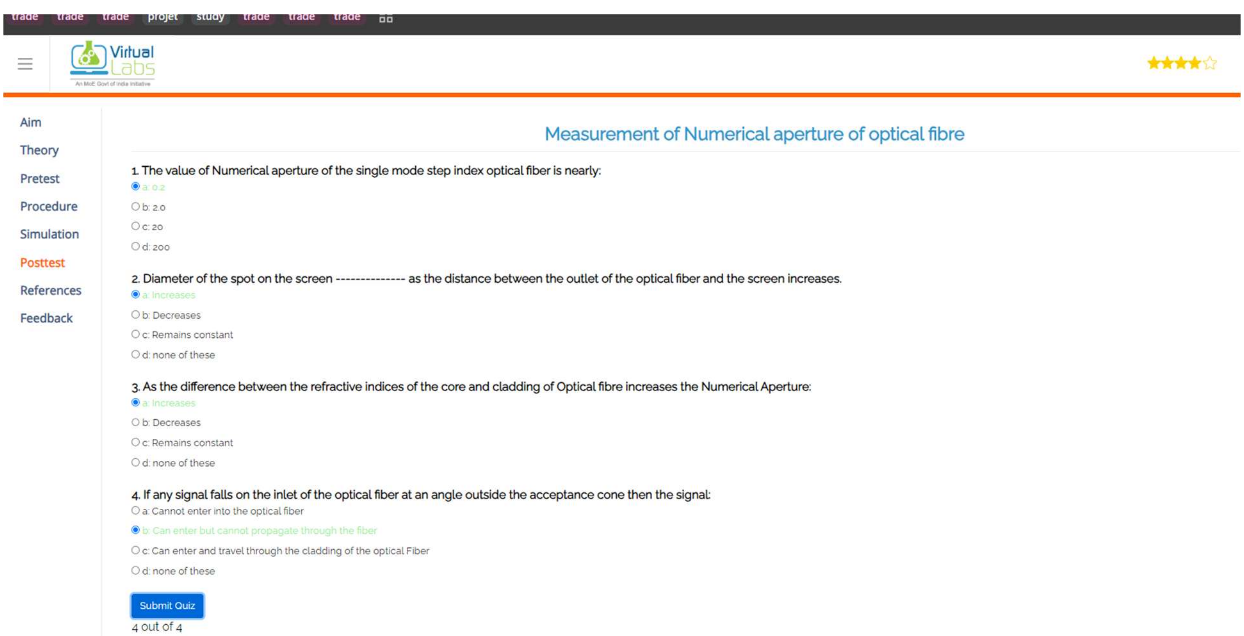
Plastic- fiber:



Glass-fiber:



Post test:



Practical Output: