LAB MANUAL

SEVENTH SEMESTER
OPTO-ELECTRONIC DEVICES

COMMUNICATION LAB
DEPARTMENT OF ELECTRICAL ENGINEERING

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Opto-Electronic Devices
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EXPERIMENT NO. 1

INTRODUCTION TO OPTOELECTRONIC DEVICES

AIM OF EXPERIMENT

The main purpose of this lab is the introduction of different optoelectronic devices, these are those devices which will come across while performing experiments in the lab.

1. **LED**

   ____________________________________________
   ____________________________________________
   ____________________________________________

2. **PHOTO TRANSISTOR**

   ____________________________________________
   ____________________________________________
   ____________________________________________

3. **FIBER OPTICS**

   ____________________________________________
   ____________________________________________
   ____________________________________________

4. **FUNCTION GENERATOR**

   ____________________________________________
   ____________________________________________
   ____________________________________________
5. **OSCILLOSCOPE**


6. **OMEGA TYPE FO-003**


EXPERIMENT NO. 2
INTRODUCTION TO OPTOELECTRONIC DEVICES TRAINER
FO-003

Object
1. To determine the Numerical Aperture of optical fibre.
2. Losses in Optical Fibres at 660nm and 850nm and other cables.
3. Study of E/O Characteristic of Fibre Optic 660nm and 850nm.
4. Study of O/E Characteristic of Fibre Optic photo transistor.
5. Design and study of a linear Fibre Optic Intensity Modulation system for analog transmission:
   5.1 Gain characteristics of a Fibre Optic Linear Intensity Modulation System.
   5.2 Frequency Response of a Fibre Optic Linear Intensity Modulation System.
   5.3 Waveform distortion in a Fibre Optic Linear Intensity Modulation system.
   5.4 Gain-Band width product of a Fibre Optic Linear Intensity Modulation System.

FEATURES

- The unit is operative on 230V ±10% at 50Hz A.C. Mains.
- Adequate no. of patch cords stackable 4mm spring loaded plug length ½ metre.
- Good Quality, reliable terminal/sockets are provided at appropriate places on panel for connections observation of waveforms.

OTHER APPARATUS REQUIRED

- AF/RF Generator 10Hz to 1MHz OMEGA TYPE AQ-309.
- Digital Fibre-Optic Power meter OMEGA TYPE DFPM-021.
- Digital Multimeter OMEGA TYPE DMM-201.
- Cathode Ray Oscilloscope 20MHz.
GENERAL INFORMATION

The Advanced Fibre Optic Analogue Transceiver Trainer FO-003 has been designed for fundamental studies on optical fibres and optical fibre communication. The experiments included for study introduce the student to basic concepts of this state-of-art technology in a simple style. The trainer includes all the accessories to conduct most of the experiments.

The three major fibre optic components, viz, the optical fibre patch cord, the optical fibre LED and the optical fibre detector are described in detail. The circuit diagram for analogue transmission employed in the Trainer Module is shown on panel. The user can design a number of other interesting experiments and small projects based on the Trainer.

The Electrical to Optical Converter converts an input voltage to an output optical power, \( P_o \), by driving the FO LED current linearly using a negative feedback operational amplifier circuit. DC LED current setting is done by rotating the knob marked LED CURRENT ADJUST. The optical power is coupled to the optical fibre through the SMA connector. LED CURRENT ADJUST sets up a dc current through the LED. The LED current can be measured by monitoring the voltage with the DMM-201 on the orange wire marked \( V_{01} \). AC input is given to the yellow wire marked \( V_{in} \). This is isolated from dc. \( V_{01}/100 \) gives the LED current, \( I_f \) in milliamps.

The optical to Electrical converter, accepts the input optical power at DET, from the optical fibre, connected via the SMA connector and provides an output voltage, \( V_o \) (Blue wire) which is directly proportional to the optical input power. For DC measurements, a DMM-201 may be used. For AC measurements, an oscilloscope is required.
EXPERIMENT NO. 3
FIBRE OPTIC TRANSMITTER THROUGH DIGITAL CIRCUIT

THEORY

As you learned in your main course, all fiber optic systems have three major elements:

- Transmitter
- Receiver
- Optical fiber

Figure 1 depicts these major elements. The transmitter and receiver contain smaller elements or building blocks, some of which you should recognize from previous activities. So far with the instructions in this manual we have made a light guide, characterized and terminated optical fibers, and evaluated LEDs and detectors. In this activity we shall investigate one of the last two elements in a fiber optic system the driver for the light source.

As you have studied, there are two commonly used light sources in fiber optics, LEDs and laser diodes. The drivers covered in this activity are for visible and infrared LEDs. We will not discuss drivers for laser diodes because they are outside the scope of this manual. They can be very sophisticated, complex, and cost thousands of dollars. There are also optical safety considerations when using laser diodes. In more advanced fiber optics classes, or in your job, you will find the information you learned here about driving LED is a good primer for laser diode driver design.

Materials Required

- Red LED (IF-E96-blue housing-pink dot)
- 2N3904
- Resistor
- Signal generator
- Multimeter
- Oscilloscope
- Solder less breadboard
PROCEDURE

1. Calculate the resistor value, $R_c$, needed to permit a current of 20 mA through the LED in Figure 3 when the transistor is saturated. Assume $V_{ce(sat)}=0.2$ volts and the $V_f$ for the LED to be 1.8 volts.

2. Calculate the maximum value of the base resistor, $R_b$, needed to drive the transistor into saturation if $V_i$ was connected to +5 volts. Assume $V_{be}=0.7$ volts and $hfe(min)=50$.

3. Choose resistors from the kit that are closest to the calculated $R_c$ and one-half the calculated $R_b$. See Table 2 for choices.

4. Assemble the circuit shown in Figure 3 on your solderless breadboard. Use the pin diagrams found to identify device connections.

5. Turn on the variable voltage power supply and adjust the output voltage to +5 volts DC.

6. Connect the end of $R_b$ marked $V_i$ to +5 volts. The red LED should now be on. If not, check the power supply and electrical connections.

7. With the multimeter measure the transistor collector-to-emitter voltage and the voltage across the LED, then record the results in Table 1.

8. Change $V_i$ from the +5 volts to ground. The red LED should now be off.

9. With the multimeter, measure the collector-to-emitter voltage across the transistor and record the result in Table 1.
RESULTS

Table 1 Measured data taken from the circuit shown in Figure 8.3.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vce (LED on)</td>
<td></td>
</tr>
<tr>
<td>Vf (LED)</td>
<td></td>
</tr>
<tr>
<td>Vce (LED off)</td>
<td></td>
</tr>
</tbody>
</table>

Analysis & Questions

Is the measured voltage across the collector of 2N3904 transistor in Figure 3 for the LED "on" and "off" compare to what you expected? Why or why not?

With the LED "on" in Figure 3 calculate the "on" current using the measured data in this activity for Vce (sat) and Vf.
EXPERIMENT NO. 4

ANALOG SIGNAL THROUGH THE OPTICAL FIBER

Apparatus:

1. Function Generator
2. Oscilloscope
3. Optical Fiber Trainer OMEGA TYPE FO-003
4. Optical fiber

Procedure

1. Generate a analog Signal from the function generator of 2Vpeak to peak with the frequency of 1KHz
2. Apply this analog Signal to the input of the Optical fiber trainer.
3. Fix the optical fiber to transmitter and receiver.
4. Adjust the gain of the system. Its gain should be 1.
5. Take the Output and measure the loss in amplitude of the signal
6. Note the input and output measured values in the table shown below
7. Draw the input and output waveforms of the signals
8. Repeat the above steps by the applying the analog input signal through function generator of 4Vpeak-to-peak with the frequency of 2KHz.

Figure. Sine Wave
Results

Table Readings at 660nm – 1m

<table>
<thead>
<tr>
<th></th>
<th>1V</th>
<th>2V</th>
<th>3V</th>
<th>4V</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1KHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table Readings at 850nm – 1m

<table>
<thead>
<tr>
<th></th>
<th>1V</th>
<th>2V</th>
<th>3V</th>
<th>4V</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1KHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**WAVE FORMS**

**INPUT WAVE FORM**

**OUTPUT WAVE FORM**
EXPERIMENT NO. 5

DIGITAL SIGNAL THROUGH THE OPTICAL FIBER

Apparatus:

5. Function Generator.
6. Oscilloscope.
7. Optical Fiber Trainer OMEGA TYPE FO-003.
8. Optical fiber.

Procedure

9. Generate a Digital Signal from the function generator of 2V peak to peak with the frequency of 1KHz.
10. Apply this Digital Signal to the input of the Optical fiber trainer.
11. Fix the optical fiber to transmitter and receiver.
12. Adjust the gain of the system. Its gain should be 1.
13. Take the Output and measure the loss in amplitude of the signal.
14. Note the input and output measured values in the table shown below.
15. Draw the input and output waveforms of the signals.
16. Repeat the above steps by applying the Digital input signal through function generator of 4V peak-to-peak with the frequency of 2 KHz.
Results:

Table Readings at 660nm – 5m

<table>
<thead>
<tr>
<th></th>
<th>1V</th>
<th>2V</th>
<th>3V</th>
<th>4V</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1KHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table Readings at 850 nm – 5m

<table>
<thead>
<tr>
<th></th>
<th>1V</th>
<th>2V</th>
<th>3V</th>
<th>4V</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500Hz</td>
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<td></td>
<td></td>
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<tr>
<td>1KHz</td>
<td></td>
<td></td>
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</tbody>
</table>

WAVE FORMS

INPUT WAVE FORM

OUTPUT WAVEFORM
**EXPERIMENT NO. 6**

**OPTICAL FIBER RECEIVER CIRCUIT**

**Equipment Required**

1. Photo Transistor
2. Resistors
3. LED
4. Power Supply
5. Multimeter
6. Solder less Bread board
7. Connecting wires

**Procedure**

1. Connect the circuit as shown in the diagram given below
2. Apply +5V potential to the collector and emitter should be grounded
3. There should be no input at the base. Do remember that base should always be kept open.
4. Measure the current properly at the emitter.
5. When we apply the light at the base of transistor the current flows through the emitter resulting in glowing the LED.
6. Measure the voltage across the Resistor when the light is applied to the phototransistor and when it is kept OFF.
7. Measure the current across the Resistor when the light is applied to the phototransistor and when it is kept OFF.

![Optical Fiber Receiver Circuit](image)

*Figure 1 Optical Fiber Receiver Circuit*
Results

<table>
<thead>
<tr>
<th></th>
<th>$V_{cc}$</th>
<th>$I_C$</th>
<th>$I_E$</th>
<th>$V_{RC}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light ON</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light OFF</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
EXPERIMENT NO. 7

TO DETERMINE THE NUMERICAL APERTURE OF OPTICAL SIGNAL

OBJECT-1: TO DETERMINE THE NUMERICAL APERTURE OF OPTICAL FIBRE AT 660 nm

The aim of the experiment is to determine the numerical aperture of the PMMA fibre cables included in the trainer.

BASIC DEFINITIONS

Numerical aperture of any optical system is a measure of how much light can be collected by the optical system. It is the product of the refractive index of the incident medium and the sine of the maximum ray angle.

\[ NA = n_1 \sin \theta_{\text{max}}; \quad n_1 \text{ for air is 1, hence } NA = \sin \theta_{\text{max}}. \]

For a step-index fibre, as in the present case, the numerical aperture is given by

\[ N = \sqrt{n_{\text{core}}^2 - n_{\text{cladding}}^2} \]

For very small differences in refractive indices the equation reduces to

\[ NA = n_{\text{core}} \sqrt{2 \Delta}, \quad \text{where } \Delta \text{ is the fractional difference in refractive indices}. \]

The experimenter may refer to the specifications of the PMMA fibre given in page no. 11 and note the manufacturer’s NA, \( N_{\text{cladding}}, \) \( n_{\text{core}} \) and \( \theta \).

The schematic diagram of the numerical aperture measurement system is shown below.

1. Connect one end of the Cable 1 (1-metre FO cable) to LED port of the trainer and the other end to the NA Jig, as shown.
2. Put the wavelength selector switch to 660nm position.
3. Plug the AC mains to ON position, neon light will come ON indicating that instrument is ready for use.

Light should appear at the end of the fibre on the NA Jig. Turn the LED CURRENT ADJUST knob clockwise to set to maximum Po. The light intensity should increase.
4. Hold the white screen with the 4 concentric circles (10, 15, 20 and 25mm diameter) vertically at a suitable distance to make the red spot from the emitting fibre coincide with the 10mm circle. Note that the circumference of the spot (outermost) must coincide with the circle. A dark room will facilitate good contrast. Record \( L \), the distance of the screen from the fibre end and note the diameter \( (W) \) of the spot. You may measure the diameter of the circle accurately with a suitable scale.

5. Compute \( NA \) from the formula \( NA = \sin 0_{\text{max}} = W/(4L^2 + W^2)^{1/2} \). Tabulate the reading and repeat the experiment for 15mm, 20mm and 25mm diameters too.

6. In case the fibre is under filled, the intensity within the spot may not be evenly distributed. To ensure even distribution of light in the fibre, first remove twists on the fibre and then wind 5 turns of the fibre on to the mandrel as shown. Use an adhesive tape to hold the windings in position. Now view the spot. The intensity will be more evenly distributed within the core.

![Diagram](image)

**TABLE OF READINGS**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>( L ) (mm)</th>
<th>( W ) (mm)</th>
<th>( NA )</th>
<th>( \theta ) (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<td>2.</td>
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</tbody>
</table>

**INFERENCES**

The numerical aperture as recorded in the manufacturers data sheet is 0.5 typically. The value measured may be 0.524 at 10mm width. The lower reading recorded is mainly due to the fibre being under filled. The acceptance angle is given by \( 2 \theta_{\text{max}} \). The value of 52 degrees recorded in the experiment is close to the range of 55 - 60 degrees. The lower reading is again due to the fibre being under filled.

*Note*: As 850nm Tx Module is Emitting Infrared Ray, so can not measure \( NA \).
EXPERIMENT NO. 8

STUDY THE OPTICAL (E-O) CHARACTERISTICS OF FIBER OPTIC 660nm CONVERTER

OBJECT-3 : STUDY OF ELECTRICAL TO OPTICAL (E-O) CHARACTERISTICS OF FIBRE OPTIC 660nm CONVERTER

The aim of the experiment is to study the relationship between the LED dc forward current and the LED optical power and determine the linearity of the device.

BASIC DEFINITIONS

LED’s and laser diodes are the commonly used sources in optical communication systems, whether the system transmits digital or analogue signals. In the case of analogue transmission, direct intensity modulation of the optical source is possible, provided the optical output from the source can be varied linearly as a function of the modulating electrical signal amplitude. LED’s have a linear optical output with relation to the forward current over a certain region of operation. It may be mentioned that in many low-cost, short-haul and small bandwidth applications, LED’s at 660nm, 850nm and 1300 nm are popular. While direct intensity modulation is simple to realise, higher performance is achieved by FM modulating the base-band signal prior to intensity modulation.

The relationship between an LED optical output $P_o$ and the LED forward current $I_F$ is given by $P_o = K I_F$, where $K$ is a constant.

The schematic diagram for characterisation of E-O converter is shown below:
**PROCEDURE**

1. Connect one end of Cable 1 to the LED port of the trainer and the other end to the power meter.
2. Put the wavelength selector switch to 660nm position.
3. Set DMM to the 200.0 mV range and connect it between the Orange wire (Vo1) and ground (Black wire) 
   \[ I_F = \frac{V_o1 \text{ (mV)}}{100} \text{ in mA} \]
4. Plug the AC mains. Adjust the LED CURRENT ADJUST knob to the extreme anticlockwise position to reduce \( I_F \) to 0. The reading on the power meter should be out of range.
5. Slowly turn the LED CURRENT ADJUST knob clockwise to increase \( I_F \). The power meter should read -30.0 dB approximately. From here change \( I_F \) in suitable steps and note the power meter readings, \( P_o \). Record up to the extreme clockwise position.
6. Plot the graph \( P_o \) vs \( I_F \) on a semilog graph sheet. Determine the slope.

**TABLE OF READINGS**

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>( V_o1 \text{ (mV)} )</th>
<th>( I_F = \frac{V_o1}{100} \text{ (mA)} )</th>
<th>( P_o \text{ (dBm)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<td>3.</td>
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<td>4.</td>
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<td>5.</td>
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<tr>
<td>6.</td>
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<td>7.</td>
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<td>8.</td>
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<td>9.</td>
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<tr>
<td>10.</td>
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</tbody>
</table>

**INFERENCES**

From the above Table it is seen that the E-O has a linear response in the 4mA to 12.0mA region.
EXPERIMENT NO. 9

TRIANGULAR WAVE THROUGH THE OPTICAL FIBER

Apparatus:
1. Communication system trainer KL-100 / ED-2960.
2. Oscilloscope.
3. Optical Fiber Trainer OMEGA TYPE FO-003.
4. Optical fiber.

Procedure

1. Generate a Triangular Signal from the communication system trainer.
2. Apply this Triangular Signal to the input of the Optical fiber trainer.
3. Fix the optical fiber to transmitter and receiver.
4. Adjust the gain of the system. Its gain should be 1.
5. Take the Output and measure the loss in amplitude of the signal.
6. Note the input and output measured values in the table shown below.
7. Draw the input and output waveforms of the signals.
8. Repeat the above steps by applying the Triangular input signal through communication system trainer at other carrier amplitudes.

Figure. Triangular Wave
Results:

Table Readings at 660nm – 5m

<table>
<thead>
<tr>
<th></th>
<th>1V</th>
<th>2V</th>
<th>3V</th>
<th>4V</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1KHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table Readings at 850 nm – 5m

<table>
<thead>
<tr>
<th></th>
<th>1V</th>
<th>2V</th>
<th>3V</th>
<th>4V</th>
</tr>
</thead>
<tbody>
<tr>
<td>100Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>500Hz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1KHz</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

WAVE FORMS

INPUT WAVE FORM

OUTPUT WAVEFORM
EXPERIMENT NO. 10

AMPLITUDE MODULATED SIGNAL THROUGH THE OPTICAL FIBER

Apparatus:

10. Oscilloscope.
11. Optical Fiber Trainer OMEGA TYPE FO-003.
12. Optical fiber.

Procedure

17. Generate a AM Signal from the communication system trainer.
18. Apply this AM Signal to the input of the Optical fiber trainer.
19. Fix the optical fiber to transmitter and receiver.
20. Adjust the gain of the system. Its gain should be 1.
21. Take the Output and measure the loss in amplitude of the signal
22. Note the input and output measured values in the table shown below
23. Draw the input and output waveforms of the signals
24. Repeat the above steps by the applying the AM input signal through communication system trainer at other carrier amplitudes.

Results:

<table>
<thead>
<tr>
<th>Input</th>
<th>Voltage</th>
<th>Power</th>
<th>Voltage</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Figure Amplitude Modulated Signal*
EXPERIMENT NO. 11

LIGHT DEPENDENT RESISTOR

The light-sensitive part of the LDR is a wavy track of cadmium sulphide. Light energy triggers the release of extra charge carriers in this material, so that its resistance falls as the level of illumination increases.

A Photoresistor is made of a high resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance.

<table>
<thead>
<tr>
<th></th>
<th>$V_{cc}$</th>
<th>$V_{RC1}$</th>
<th>$V_{LDR}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light ON</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light OFF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHANGE</td>
<td></td>
<td></td>
<td>---------</td>
</tr>
</tbody>
</table>
EXPERIMENT NO. 12

PHOTOVOLTAIC CELL

Photovoltaics is the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results that can be used as electricity.

<table>
<thead>
<tr>
<th>Light ON</th>
<th>V_0</th>
<th>V_R6</th>
<th>V_R8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light OFF</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
EXPERIMENT NO. 13

MAKING A LIGHT GUIDE CIRCUIT

Theory

In this activity you will construct a simple light guide using water and a length of vinyl tubing. The water and vinyl tubing will act as the core, while air will act as the cladding or boundary layer. The experiment will demonstrate how effective even a simple light guide is for coupling energy from a light source to a detector. You will also observe how the light guide can carry light “around a corner” with relatively little loss compared to when light travels in a straight line.

![Cross section of an optical fiber with a light ray traveling down the core.](image)

Materials Required

- Red LED
- Phototransistor (T 1 3/4 package)
- Vinyl tubing, 15 cm
- 150 Ω resistor
- Eye dropper
- Solderless breadboard
- Single-edge razor blade or sharp knife
- Paper towels
- Small, shallow, water-tight pan
- Miscellaneous electrical test leads
- Multimeter
- Distilled Water
- Variable voltage power supply

Procedure

1. Using a single-edge razor or sharp knife trim a small amount from the ends of the vinyl tubing so that they are clean and square (90 degrees).
2. Insert the red flat-topped LED into one end of the vinyl tube. Be sure to insert the LED all the way into the tubing to ensure a tight fit.
3. Insert the phototransistor (T 1 3/4 package) into the other end of the vinyl tubing. Push the phototransistor in completely for a tight fit.
4. Turn on the variable voltage power supply and adjust the output to ± 5 volts DC.
5. Set the function of the multimeter to read "Current" on the 2 mA scale.
6. On your solderless breadboard connect the electrical circuits as shown. Use the device diagrams found in the to identify anode and cathode on the LED, and collector and emitter on the phototransistor. (The Phototransistor and multimeter circuit will function as an inexpensive radiometer to evaluate the light guide. This type of circuit photo detector/multimeter) will be used as a radiometer throughout this manual.)
7. Light should be visible from the red LED at this point. If not, check the electrical connections to the LED.
8. The multimeter should indicate current flow through the phototransistor. If not, check the electrical connections and correct polarity for the phototransistor.
   To obtain best results in this activity, you may need to dim the room lights or cover the light guide with a dark cloth or box. This will minimize the chance of ambient light being captured by the phototransistor, and improve the accuracy of your measurements.
9. In Table 1 record the current measured by the multimeter (LED ON).
10. Disconnect the 150 Ω resistor from the +5 volt power supply, which will turn the LED off.
11. In Table 1 record the current measured by the multimeter through the phototransistor with the LED off.
12. Remove the vinyl tubing, red LED and phototransistor as an assembly from the solderless breadboard. Pull the red LED from the vinyl tubing (leaving the phototransistor in), and slowly fill the vinyl tubing with distilled water using the eyedropper. Do not hurry when filling the tubing; try to put in a drop at a time to avoid leaving any air bubbles in the tubing. Bubbles will scatter some of the light being transmitted through the water.
13. Re-insert the red LED in the vinyl tubing and push in completely for a tight fit to prevent water from leaking out. Make certain there are no air bubbles inside the tubing between the red LED and phototransistor. Refill as necessary during the experiment if any water leaks out.
14. Re-connect the red LED and phototransistor to the circuit on the solderless breadboard. Re-connect the 150 Ω resistor to the +5 volt power supply. In Table 2 record the current measured by the multimeter (LED ON).
15. Disconnect the 150 Ω resistor from the +5 volt power supply, which will turn the LED off. In Table 2 record the current measured by the multimeter through the phototransistor with the LED off.
16. Gently make a 90-degree bend in the light guide and repeat steps 14 and 15. Be careful to not let any water leak out from the light guide — refill if necessary. Record the data in Table 3.
17. Dip the light guide into a pan of water. Describe below what happens to current measured by the multimeter, and what happens to the red LED light. (It may help to dim the room lights to view the LED light better.)
18. Turn off the power supply and return all items to their proper storage containers and locations.
RESULTS

Table 1  Empirical data for 15 cm (6-inch) light guide with air core.

<table>
<thead>
<tr>
<th>LEDs</th>
<th>LED OFF</th>
<th>LED ON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2  Empirical data for 15 cm light guide with water core.

<table>
<thead>
<tr>
<th>LEDs</th>
<th>LED OFF</th>
<th>LED ON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3  Empirical data for light guide with 90-degree bend.

<table>
<thead>
<tr>
<th>LEDs</th>
<th>LED OFF</th>
<th>LED ON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analysis & Questions

What is the amount of light in milliwatts (mW) that falls on the phototransistor when using the red LED with the light guide and water core [assuming the responsivity of the phototransistor to be 50 milliamperes / milliwatts (mA/mW)]? What is it with no water in the core?

Does the light guide send more or less light onto the phototransistor with water in the core? Why?

Did the 90-degree bend significantly change the amount of light hitting the phototransistor? Why or Why not?
EXPERIMENT NO. 14

LOSSES IN OPTICAL FIBER AT 660NM

OBJECT-2 : LOSSES IN OPTICAL FIBRE AT 660nm, 850nm AND CABLES.

The aim of the experiment is to study various types of losses that occur in optical fibres and measure the loss in dB of two optical fibre patch cords. The coefficient of attenuation per metre is to be computed from the results.

BASIC DEFINITIONS

Attenuation in an optical fibre is a result of a number of effects. This aspect is well covered in the books referred to in references. We will confine our study to attenuation in a fibre due to macro bending and estimate the losses in two patch cords and loss per meter of fibre in dB. We will use the two patch cords and the inline adaptor provided in the kit. Fibre loss variations with wavelength for the PMMA fibre under consideration is shown in page no. 11. However this is not measurable here.

The optical power at a distance, L, in an optical fibre is given by

\[ P_L = P_0 \times 10^{-\alpha L/10} \]

where \( P_0 \) is the launched power and \( \alpha \) is the attenuation coefficient in decibels per unit length. The typical attenuation coefficient value for the fibre under consideration here is 0.3 dB per metre at a wavelength of 660nm. Loss in fibres expressed in decibels is given by -10log (Po/PF) where, \( P_0 \) is the launched power and \( P_F \) is power at the far end of the fibre. Typical losses at connector junctions may vary from 0.3 dB to 0.6 dB.

Losses in fibres occur at fibre-fibre joints or splices due to axial displacement angular displacement, separation (air core), mismatch of cores diameters, mismatch of numerical apertures, improper cleaving and cleaning at the ends. The loss equation for a simple fiberoptic link is given as:

\[ \text{Pin (dBm)} - \text{Pout (dBm)} = L_{J1} + L_{F1} + L_{J2} + L_{F2} + L_{J3} \]

where, \( L_{J1} \) (dB) is the loss at the LED-connector junction, \( L_{F1} \) (dB) is the loss in cable 1, \( L_{J2} \) (dB) is the insertion loss at a splice or in-line adaptor, \( L_{F2} \) (dB) is the loss in cable 2 and \( L_{J3} \) (dB) is the loss at the connector-detection junction.

The schematic diagram of the optical fibre loss measurement system is shown below:
PROCEDURE
1. Connect one end of Cable 1 to the LED port of the trainer and the other end to the power meter.
2. Put the wavelength selector switch to 660nm position.
3. Turn the Power meter ON. DPM will be ON indicating that power meter is ready for use.
4. Plug the AC mains neon light will come on indicating that instrument is ready for use. Connect the optical fibre patch cord securely, as shown after relieving all twists and strains on the fibre. Adjust the LED CURRENT ADJUST knob to set Po of the LED to a suitable value, say, -15.0 dBm. On the power meter. Note this as Po1.
5. Wind one turn of the fibre on the mandrel as shown in Experiment 1 and note the new reading of the power meter Po2. Now the loss due to bending and strain on the plastic fibre is Po1 - Po2 dB. For more accurate readout set the power meter to the -20 dBm to -10 dBm range and take the measurement. Typically the loss due to the strain and bending the fibre is 0.3 to 0.8 dB.
6. Next remove the mandrel and relieve cable 1 of all twists and strains. Note the reading Po1. Repeat the measurement with Cable 2 (5 metres) and note the reading Po2. Use the in-line SMA adaptor and connect the two cables in series as shown below. Note the measurement Po3.

Po3 - Po1 gives loss in the second cable plus the loss due to the in-line adaptor Po3 - Po2 gives loss in the first cable plus the loss due to the in-line adaptor. Assuming a loss of 1.0 dB in the in-line adaptor, we obtain the loss in each cable. The difference in the losses in the two cables will be equal to the loss in 4 metres of fibre (assuming that the losses at connector junctions are the same for both the cables). The experiment may be repeated in the higher sensitivity range of -20 dBm. The experiment also may be repeated for other values of Po, say -20 dBm, -25 dBm and -30dBm.
7. Now put the wave selector switch to 850nm position and repeat procedure no. 3 to 6. The 850nm transmitter will not give any light and optical power will be less comparison to 660 nm transmitter.
EXPERIMENT NO. 15

FREQUENCY MODULATED SIGNAL THROUGH THE OPTICAL FIBER

Apparatus:

13. Communication system trainer KL-100 / ED-2960.
15. Optical Fiber Trainer OMEGA TYPE FO-003.
16. Optical fiber.

Procedure

25. Generate a FM Signal from the communication system trainer.
26. Apply this FM Signal to the input of the Optical fiber trainer.
27. Fix the optical fiber to transmitter and receiver.
28. Adjust the gain of the system. Its gain should be 1.
29. Take the Output and measure the loss in amplitude of the signal
30. Note the input and output measured values in the table shown below
31. Draw the input and output waveforms of the signals
32. Repeat the above steps by applying the FM input signal through communication system trainer at other carrier amplitudes.

Results:

<table>
<thead>
<tr>
<th>Input</th>
<th>Voltage</th>
<th>Power</th>
<th>Voltage</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure. Frequency Modulated Signal
EXPERIMENT NO. 16

LOSSES IN OPTICAL FIBER AT 850NM

OBJECT–2 : LOSSES IN OPTICAL FIBRE AT 660nm, 850nm AND CABLES.

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The optical power at a distance, L, in an optical fibre is given by

\[ P_L = P_0 10^{-\alpha L/10} \]

where \( P_0 \) is the launched power and \( \alpha \) is the attenuation coefficient in decibels per unit length. The typical attenuation coefficient value for the fibre under consideration here is 0.3 dB per metre at a wavelength of 660nm. Loss in fibres expressed in decibels is given by -10log(\( P_0/P_F \)) where, \( P_0 \) is the launched power and \( P_F \) is power at the far end of the fibre. Typical losses at connector junctions may vary from 0.3 dB to 0.6 dB.

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\[ \text{Pin (dBm)} - \text{Pout (dBm)} = L_{J1} + L_{FB1} + L_{J2} + L_{FB2} + L_{J3} \] (dB), where, \( L_{J1} \) (dB) is the loss at the LED connector junction, \( L_{FB1} \) (dB) is the loss in cable 1, \( L_{J2} \) (dB) is the insertion loss at a splice or in-line adaptor, \( L_{FB2} \) (dB) is the loss in cable 2 and \( L_{J3} \) (dB) is the loss at the connector-detection junction.

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![Diagram showing Po, Po1, Po2, Po3](image)

Po3 - Po1 gives loss in the second cable plus the loss due to the in-line adaptor Po3 - Po2 gives loss in the first cable plus the loss due to the in-line adaptor. Assuming a loss of 1.0 dB in the in-line adaptor, we obtain the loss in each cable. The difference in the losses in the two cables will be equal to the loss in 4 metres of fibre (assuming that the losses at connector junctions are the same for both the cables). The experiment may be repeated in the higher sensitivity range of -20 dBm. The experiment also may be repeated for other values of Po, say -20 dBm, -25 dBm and -30dBm.
7. Now put the wave selector switch to 850nm position and repeat procedure no. 3 to 6. The 850nm transmitter will not give any light and optical power will be less comparison to 660 nm transmitter.