Chapter 1

1310 nm Optical Fiber Transceiver

I. Curriculum Objectives

1. To understand the operation theory of optical fibers.
2. To understand the operation theory of optical fibers transmitter circuit.
3. To design and implement the 1310 nm optical fibers transmitter.
4. To measure and adjust the 1310 nm optical fibers transmitter.

II. Curriculum Theory

1-1 The Typical Optical Fibers Transmission Systems

In human societies, people of different eras would use different ways to interact or to share their information; the methods for transmissions of information are called "communication". Starting from the ancient beacon towers, pigeon mail, it has revolved until the mobile phones and satellite communicating. As long as humans are in different existing environments, they would develop appropriate communication systems; no matter how the systems change, the purpose to communicate would remain the same. Among various kinds of communicating systems, the basic form always consists of the sender, the media, and the receiver. Also, following the categories of the media, there are two types of systems: the first is wireless, which transmits through air; and the other is wired, which transmits through cables or optical fibers.

Figure 1-1 is a picture of the basic structure of a communicating system; the message to be sent is at the sender. The feature of this message (such as the formations, the frequencies, or the voltage amplitudes), however, must meet the state of same transmitting media, so that to allow the receiver to receive it correctly.

Figure 1-2 is the block diagram of the optical fibers transmission system. In figure 1-2, we can see that the optical fibers transmitter includes modulator, driver and E/O converter; the optical fibers receiver includes demodulator, optical detector and amplifier; the data channel uses optical fibers as the guided line. In this chapter, we will discuss the characteristics of optical fibers transmitter.

Figure 1-1 The basic communication system.

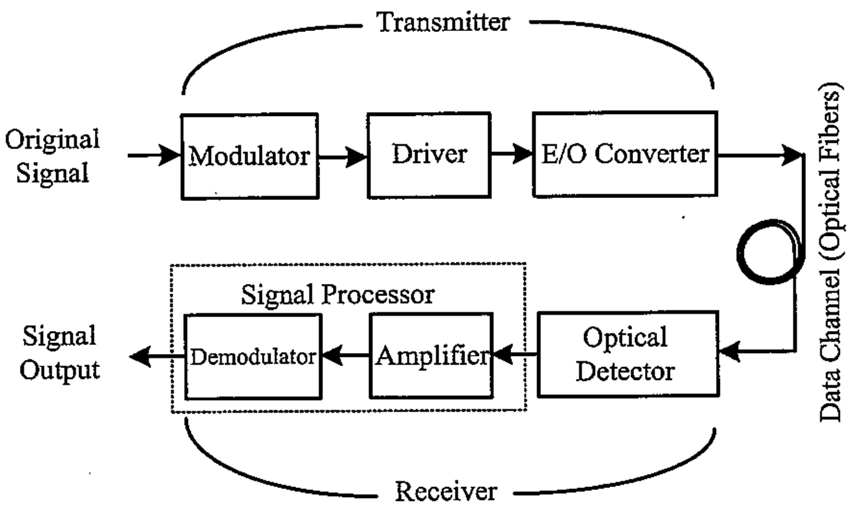


Figure 1-2 The block diagram of optical fibers transmission system.

1-2 The Original Message

An original signal could be a sound wave, an image, or the signal of a natural phenomenon; though none of these signals could be sent directly through optical fibers, because in optical fiber transmitting systems, it is the shading values of the light that is adopted to send messages. To control the variation of shading values on the light emitter, the simplest way is to change the amount of the current that flows through it. According to Ohm's law, it is known that the current can be obtained through dividing the voltage by the resistor ($I=\frac{V}{R}$); transforming the original messages to an electrical signal would make it more convenient in sending. Furthermore, the major function of a transducer is to transform non-electrical messages to electrical ones, such as: a microphone that transforms sound waves to electrical signals, or a video camera that transforms images to electrical signals.

1-3 Modulators/Converters

Main functions of modulators/converters are converting electrical signals with different states or features with each other, to allow optical fibers to send original information more efficiently. Assume that a signal that changes really slowly and has rather small amplitudes, like, the signal from a thermograph, is to be sent; in normal environments, thermal changes perform really slowly that would still be the same after transformed to electrical signals, and therefore errors on voltage accuracy would easily occur when sending a signal that is approximately the same as the direct voltage of the current through optical fibers.— this is because the shading values at the receiver would differ according to the sending distance. Such conditions would cause great disturbances in practical applications, and thus requires a modulator or a converter to prevent them from happening.

1-4 Driver

The major functions for a driver are to enable the light emitting facility to correctly transform signals of the voltage to signals of the light. Shadings values can be controlled via outer current in most of light emitting facilities; when the input current is too small or not enough for light emitting facilities to perform correctly, a driver shall be used to enlarge the input current. Using this feature correctly allows light emitting facilities to perform correctly under control.

1-5 Signal Processors

Signal processors are mainly used to modulate or counter-convert signals they receive, so that original messages sent would be obtained. Following various function requirements, signal processors can be divided into 4 sub-electrical circuits: 1. Signal amplitude oscillators. 2. Voltage polarity transformers. 3. Noise filtrating circuits. 4. Signal demodulators/reverting circuits. The most frequently used circuits are the demodulators/ reverting circuits and the amplitude oscillators; and the other two would be added or eliminated according to different situations and requirements.

Signal amplitude oscillators are used for oscillating those small signals received to satisfy the electrical specs in latter-level circuits. And voltage polarity transformers are used to transfer output bipolarity signals from oscillators to single-polarity signals, or else, transform the voltages between signals; for instance, transforming an input $12\ V$ to a $5\ V$ output signal. Also, noise filtrating circuits can filtrate the noises that should be eliminated in signals, in case rubbish noises make the circuit misact. As for signal demodulators / reverting circuits, they deal with input signals, then eventually output reverted data signals.

1-6 1310 nm Optical Fiber Transceivers

After introducing part of the block diagram of optical fiber transceivers, the axioms and circuit features of a 1310 nm optical fiber transceiver shall be discussed and introduced as follows:

(1) Transmitters

Figure 1-3 is the circuit diagram of a 1310 nm optical fiber transmitter. The function of NAND U_1 is the buffer with its major purpose on adding capabilities to fan out; the other main function of this NAND is to revert the amplitude accuracy of the signal that is diminished. The electrical resistor R_1 is a promoting resistor that primarily assists to prevent loading effects from happening, while resistor R_2 and R_3 are limiting resistors that prevent the IC from burning when the output voltage of $U_1:B$ and $U_1:C$ is too low ($0\ V$), which would cause large amount of current flow toward the inside of the IC. Also, resistor R_4 and capacitor C_2 are consisted as a low-pass filter that filtrates rubbish noises on the power, while capacitor C_3 is a speed-up capacitor to shorten the interacting time of voltage differences on the two sides of resistor R_5. Resistor R_6 and the variable resistor VR_1 are mostly used to offer bias for the LED (light emitting diode). Through adjusting the resistance value resistor VR_1, the amount of current that flows through the LED can be changed, which indirectly changes the intensity of the LED, allowing both transmitting and receiving to perform normally.

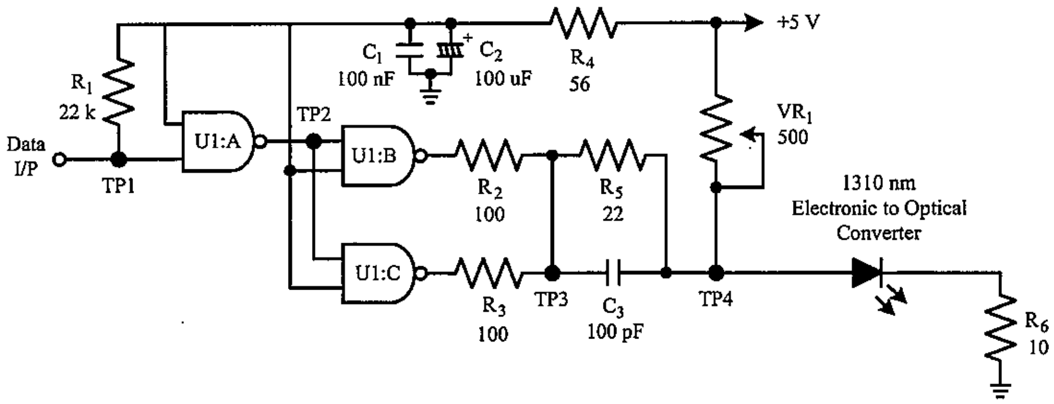


Figure 1-3 The circuit diagram of a 1310 nm optical fiber transmitter.

(2) Receivers

Figure 1-4 is the circuit diagram of a 1310 nm received signal processor. As received amplitudes of digital signals could be either very small or full of noises, the IC the amplitude magnifier produced by Motorola, with spec number MC10116, would be used to deal with digital signals. Same amplitude magnifier has a great CMRR (Common Mode Rejection Ratio) and is very proper for long-distance circuit transmissions.

In the circuit shown in Figure 1-4, three amplitude magnifiers in total are used to ensure that signals are efficiently magnified as rubbish noises carried during transmissions would be eliminated. ◦ Transistor Q_1 and Q_2 are consisted as another amplitude magnifier with its means to handle the voltage accuracy processes for output signals from MC 10116, because the output voltage of MC 10116 cannot achieve the accuracy for TTL signals, which shall be accomplished through the conducting (on) and cutting (off) of the transistors; this also refers to design transistor Q_1 and Q_2 in the working mode as a switch. When the opposite output end of $U_1:C$ is in high voltage ($5\ V$), transistor Q_2 works at the cutting section, and thus the output of Data O/P would be low (0 V); on the contrary, if the opposite output end of $U_1:C$ is in low voltage (0 V), transistor Q_2 works at the conducting section, with the output of Data O/P in high voltage (5 V). The output amplitude can also be adjusted through resistor R_{14}; the amplitude shall turn bigger with the resistance value increasing. Though, if the resistance on resistor R_{14} is too big, the output waves would be affected; this is because when transistor Q_2 is cut, the voltage on Data O/P would release electricity to the ground through resistor R_{14} at the same time; as resistor R_{14} becomes too big, the releasing time would extend, which causes extensions of voltage dropping time that would lead to distortion of the output wave.

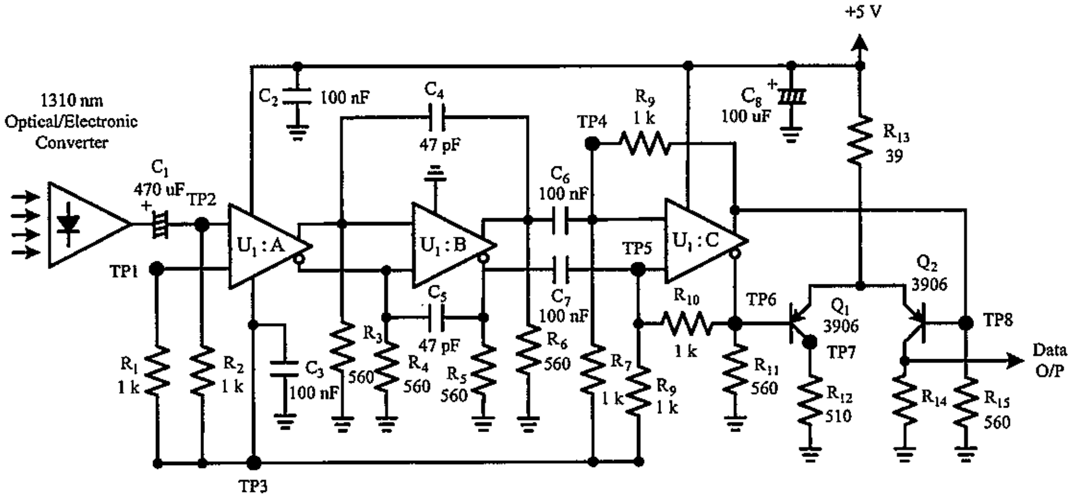


Figure 1-4 The circuit diagram of a 1310 nm received signal receiver.

III. Experiment Items

Experiment 1: The Transmitting Circuit of 1310 nm

1. Assemble the 1310 nm optical fiber transmitter shown as Figure 1-3, or refer same assembly to the OFS1-1 in the models of ETEK OFS-9500-01.

2. Enter a TTL wave with 5 V amplitude, 50% working circle and 10 kHz frequency, at the digital signal input end (Data I/P). Use an oscilloscope to observe respectively on the input end of Level-1 phase reverser (TP1), the output end of Level-1 phase reverser (TP2), the output end of Level-2 phase reverser (TP3), and the input end of 1310 nm optical fiber (TP4); meanwhile, adjust the variable resistor VR_1 at the same time, so that output signals from TP4 would reach the maximum without distortions. Record the observed outcomes in table 1-1.

3. Repeat Step 2 following the input signals shown in table 1-2, and record the observed outcomes in table 1-2.

Experiment 2: The Receiving Circuit of 1310 nm

1. Assemble the 1310 nm optical fiber receiver as shown in Figure 1-4, or refer same assembly to the 1310 nm receiving circuit shown in OFS2-1, in the models of ETEK OFS-9500-02. Also, assemble the 1310 nm optical fiber transmitter shown as Figure 1-3, or refer same assembly to the OFS1-1 in the models of ETEK OFS-9500-01.

2. Enter a TTL wave with 5 V amplitude, 50% working circle and 10 kHz frequency, at the digital signal input end of OFS1-1 (Data I/P). Use optical fibers to connect OFS-01 and OFS-02 models respectively.

3. Use an oscilloscope to observe the 1310 nm optical fiber input end (TP4) on OFS1-1 and adjust the variable resistor VR_1, so that output signals from TP4 would reach the maximum without distortions. Record the observed outcomes in

table 1-3.

4. Use the oscilloscope to observe the input end of electrode base bias (TP3) on OFS2-1, and record the observed outcomes in table 1-3.

5. Use the CH1 and CH2 on the oscilloscope at the same time to observe input end of Level-1 phase non-reverser (TP1) as well as the input end of Level-1 phase reverser (TP2), and record the observed outcomes in table 1-3.

6. Use the CH1 and CH2 on the oscilloscope at the same time to observe input end of Level-3 phase non-reverser (TP4) as well as the input end of Level-3 phase reverser (TP5), and record the observed outcomes in table 1-3.

7. Use the CH1 and CH2 on the oscilloscope at the same time to observe input end of Level-3 phase non-reverser (TP6) as well as the input end of Level-3 phase reverser (TP8), and record the observed outcomes in table 1-3.

8. Use the CH1 and CH2 on the oscilloscope at the same time to observe both electrode collecting ends of transistor Q_1(TP7) as well as transistor Q_2(Data O/P), and record the observed outcomes in table 1-3.

9. Repeat Step 4 to Step 8 following the input signals shown in table 1-4, and record the observed outcomes in table 1-4.

IV. Experiment Results

Table 1-1 The measured results of 1310 nm transmitter circuit.

Input Signal Frequencies and Amplitudes	Output Signal Waveforms	
TTL (50 %) @ 10 kHz	TP1	TP2
	TP3	TP4
TTL (50 %) @ 50 kHz	TP1	TP2
	TP3	TP4

Table 1-2 The measured results of 1310 nm transmitter circuit.

Input Signal Frequencies and Amplitudes	Output Signal Waveforms	
TTL (33 %) @ 10 kHz	TP1	TP2
	TP3	TP4
TTL (33 %) @ 50 kHz	TP1	TP2
	TP3	TP4

Table 1-3 The measured results of 1310 nm receiver circuit.

<table>
<tr><td>Input Signal Frequencies and Amplitudes</td><td colspan="2">Output Signal Waveforms</td></tr>
<tr><td rowspan="6">TTL (50 %)
@ 10 kHz</td><td>TP4 (OFS1-1)</td><td>TP3</td></tr>
<tr><td></td><td></td></tr>
<tr><td>TP1、TP2</td><td>TP4、TP5</td></tr>
<tr><td></td><td></td></tr>
<tr><td>TP6、TP8</td><td>TP7、Data O/P</td></tr>
<tr><td></td><td></td></tr>
</table>

Table 1-3 The measured results of 1310 nm receiver circuit (cont.).

Input Signal Frequencies and Amplitudes	Output Signal Waveforms	
TTL (50 %) @ 50 kHz	TP4 (OFS1-1)	TP3
	TP1 、TP2	TP4 、TP5
	TP6 、TP8	TP7 、Data O/P

Table 1-4 The measured results of 1310 nm receiver circuit.

Input Signal Frequencies and Amplitudes	Output Signal Waveforms	
TTL (33 %) @ 30 kHz	TP4 (OFS1-1)	TP3
	TP1 、TP2	TP4 、TP5
	TP6 、TP8	TP7 、Data O/P

Table 1-4 The measured results of 1310 nm receiver circuit (cont).

Input Signal Frequencies and Amplitudes	Output Signal Waveforms	
	TP4 (OFS1-1)	TP3
TTL (33 %) @ 50 kHz	TP1 、TP2	TP4 、TP5
	TP6 、TP8	TP7 、Data O/P

V. Problems Discussion

1. Please describe a typical block diagram of optical fiber transmission system, which block circuits be included ?
2. In accordance with the various transmission mediums, which the types of the optical fibers can be classified ? and what are their application?
3. What are the functions of the modulator, converter, and driver?
4. What are the functions of the resistors R_2, R_3 and capacitor C_3 in figure 1-3?
5. What are the functions of Q_1 and Q_2 in the differential circuit in figure 1-4?

Chapter 2

1550 nm Optical Fiber Transceiver

I. Curriculum Objectives

1. To understanding the features of optical fiber wiring materials.
2. To understand the operation theory of optical fibers transmitter circuit and optical detector.
3. To design and implement the 1550 nm optical fibers transmitter.
4. To measure and adjust the 1550 nm optical fibers transmitter.

II. Curriculum Theory

The light resource for optical fiber usages started from lights with its wavelength of 0.8 micrometer then changed to another with its wavelength of 1.3 micrometer; until now, the best is 1.55 micrometer. Although lights with wavelengths from 1.3 to about 1.6 micrometer are suitable for communications, according to researches, the near-infrared light with a wavelength of 1.55 micrometer is the best, as its wastage during transmissions is capable of reaching the lowest. In the proceeding of light improvement in Massachusetts Institute of Technology in 1988, lights of a wavelength of 1.4 micrometer was already overcome; though the disadvantage of it was that the wastage would become too big as it would be suckled through humidity. In Chapter One, when 1310 nm optical transceivers were introduced, functions of parts of the circuit diagram region were illustrated as well. Next, illuminators, photodiodes, the transmitting media (optical fibers), and 1550 nm optical transceivers shall all be introduced, as features of circuit diagrams of each of them are narrated as follows:

2-1 Illuminators

From Figure 2-1, signals that are moderated (transformed) will eventually be sent to the illuminating facility. Twp types of the most frequently used light resources are: first, Light Emitting Diodes (LED), and second, Laser Diodes (LD).

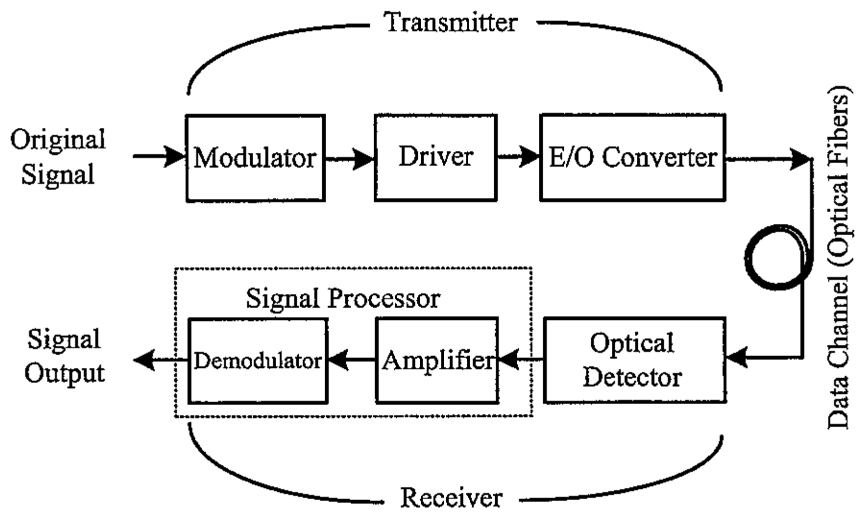


Figure 2-1 The block diagram of optical fibers transmission system.

(1) light Emitting Diode, LED

Light Emitting Diodes (LED) was developed in the laboratory at the end of the 1950s; in 1968, HP started massive production and commercializing of it, with single and dull dark red only. When Nichia had a breakthrough on technical barriers of blue LED in 1992, LED with multiple colors and enhanced luminance were gradually generated.

The illuminating axiom for LED is a direct transformation of electricity to light; the principle of this transformation is to add a directive forward voltage at the PN side of a semiconductor, so that electrons would receive energy; oppositely, when electrons integrate with the electron holes, electron would release the energy left as the form of light. With different materials, energy levels would differ as well; with different energy level, the amount of received energy for photons would be affected, too, and thus wavelengths of lights shall differ. Lights with different colors that human eyes are capable of sensing have wavelengths between $400-780\,\mathrm{nm}$; others that are not in this zone are called “invisible lights”.

(2) Fabry Perot Laser

FP Laser was the Laser Diode (LD) earliest for communication. Commonly seen wavelengths of FP Lasers are 850 nm and 1310 nm; its features of high power ratios (about a couple of mW) and narrow spectral widths make it possible of being a light source for longer distance communications (commonly, the distance of telecommunications is around 30 km) 。

The biggest difference between LD and LED in structures is that LD obtains a resonating housing structure. To make it simple, the current would be provided to the resonating housing, so that the electrons in the housing would release photons due to the transitions of the range of energy, as shown in Figure 2-1. The inner sides of the housing can be taken as two parallel mirrors; as the inward refraction ratio is higher than the outside, photons would gather inside the housing; when the energy accumulates to a certain degree, it shall transmit through the housing. In table 1-1, the comparison on features between LD and LED is presented.

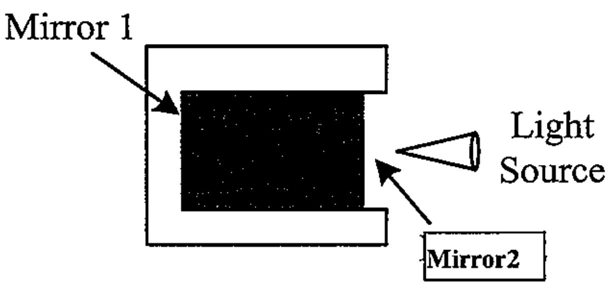


Figure 2-2 A diagram of a resonating housing structure.

Table 2-1 Comparison on features between LD and LED

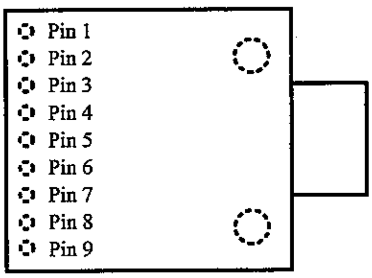
Features	LED	LD
Output Power	Low	High
Speed	Slow	Fast
Spectral Width	Wide	Narrow
Single Model Compatibility	None	Obtained
Convenience in Using	Easier	Difficult
Lifespan	Long	Long
Capitals	Low	High

2-2 Photodiodes

Table 2-3(a) is an optical fiber transceiver. The facilities from BAYCOM Opt-electronics are adopted in the experiment, with their registration numbers TB1-S4-2205 and TB1-S3-2205. Both of them contain an illuminator and a photodiode; following different working environments, voltages of 3.3 V and 5 V are divided, which make it more convenient in using. ∘ The illuminator of TB1-S4-2205 has a wavelength of 1550 nm, while its photodiode has a wavelength of 1310 nm. Also, the illuminator of TB1-S3-2205 has a wavelength of 1310 nm, while its photodiode has a wavelength of 1550 nm. Both the two optical fiber transceivers have working pressures of 5 V, and are capable of using single optical fiber to achieve a full duplex transmissions. Table 2-3(b) is the description for functions of the pins on optical fiber transceivers.

Table 2-3 An optical fiber transceiver. (a) Diagram of pins. (b) Descriptions for pins.

(a) Diagram of pins.



(b) Descriptions for pins.

Pin	Description
Pin 1	**Receiver end of signals.**
Pin 2	**Output of received signals.**
Pin 3	**Opposite output for received signals.**
Pin 4	**Signal detector.**
Pin 5	**Power receiver.**
Pin 6	**Power transmitter.**
Pin 7	**Input of transmitted signals.**
Pin 8	**Opposite input of transmitted signals.**
Pin 9	**Transmitting end of signals.**

2-3 Transmitting Media (Optical Fibers)

In 1966, Professor Charles K. Kao has released his prose of Dielectric-Fiber Surface Waveguides for Optical Frequencies, offering concepts of making high, pure glass fibers from silica for long-distance telecommunications, which started the era of optical fiber telecommunications. Silica can usually seen at the beach — the gravel, of which the ore body is large in the planet. That is why materials for optical fiber manufacturing are very cheap.

(1) Structures and Types of Optical Fibers

One of the advantages for optical fibers is the wastage during transmissions is very low. Generally, for copper conducting wires, 20 decibels would be wasted every kilometer; during long-distance transmissions, large amounts of relays must be set for signal strength enlarging. On the other hand, using optical fiber transmissions, the wastage is only one of a hundred comparing with copper conductors, which is only 0.2 decibels each kilometer.

The basic structure of optical fibers is shown in figure 2-4. The center part is the core, which its element is glass. The core is covered with cladding, which is also made by glass. The outer shield is the coating, which is used to protect the optical fibers and strengthen the intensity of mechanism. Generally, the element of the outer shield is acrylic or silicone. The typical core diameter of optical fibers is about 50 ~ 100 μm and the coating diameter is about 100 ~ 200 μm.

According to the transmission mode, the optical fibers can be classified into single mode fiber and multi-mode fiber. Single mode fiber is mainly used for long distance, large capacity and high-speed transmission. The diameter of multi-mode fiber is larger and has the advantage of fast connection; therefore, it is mainly applied at the short distance area with small transmission capacity such as local area network (LAN), inside the multi-storey building and so on.

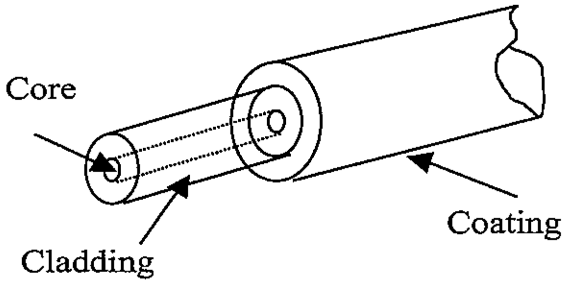


Figure 2-4 The basic structure of optical fibers.

In accordance with the various types of fabricated material, the optical fibers can be classified as quartz fiber, multi-element glass fiber and plastic fiber. The core and cladding of quartz fiber is comprised by quartz glass of SiO_2. Then the core and cladding of multi-element glass fiber is comprised by SiO_2, B_2O_3, Na_2O, Tl_2O and so on. As for plastic fiber, the core is made by polymethyl methacrylate (PMMA) or polystyrene (PS) and the cladding is made by high polymer fluoride or PMMA. Although the melting point of multi-element glass fiber and plastic fiber is low and can be melted in platinum or quartz crucible, both of them will interfere with metal ions such as iron, copper, nickel and other impurities. These impurities will increase the losses of optical fibers, which means the characteristics of transmission loss and bandwidth are not as good as quartz fiber, therefore, the main material of optical fiber in the market is still the quartz series optical fibers.

On the other hand, in accordance with the suitable application in certain environment, the optical fibers can be classified as pipeline used, direct buried used, indoor used, built on stilts used, undersea used and so on.

(2) Data Channel

Data channel is the route between the transmitter and receiver. In optical fibers communication system, the fiber, which is made by glass or plastic, is a kind of channel. However, the required characteristics of data channel are low power attenuation and high cone angle of acceptance.

In optical fiber systems, as most of the fiber centers are rather small, with diameters around 50 μm; though the range of angles for light transmitting is too large, which means optical fibers can merely capture lights in limited angles. In Figure 2-5, the light transmitter is tightly closed to optical fibers, as the optical fibers are large enough to capture all the lights transmitted from the light source; though, the real truth is, these optical fibers cannot completely capture all lights. That is why a cone-shaped angle optically large is needed to decrease the loss of the light source.

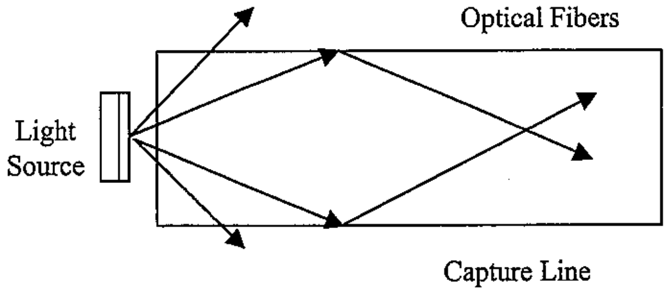


Figure 2-5 The diagram of light couples to optical fibers.

2-4 1550 nm Optical Fiber Transceivers

After introducing sub-electric circuits for optical fiber transceivers, the transmitting axioms and circuit features of 1550 nm optical fiber transmissions shall be discussed; though, as the circuit diagram is approximately the same as the other 1330 nm mentioned in the former chapter, only the differences would be illustrated as follows:

(1) Transmitter

Figure 2-6 is a 1550 nm transmitter that uses differential structures to transmit data. The amplitude magnifier IC produced by Motorola, with registration number MC 10116 will be adopted to transform input signals to amplified signals. Transistors Q_1 and Q_2 are composed as another set of amplitude magnifier, which is used to increase the current flowing through illuminator D_1 and D_2; this is used to enhance the luminance transmitted into optical fibers for further transmitting distance.

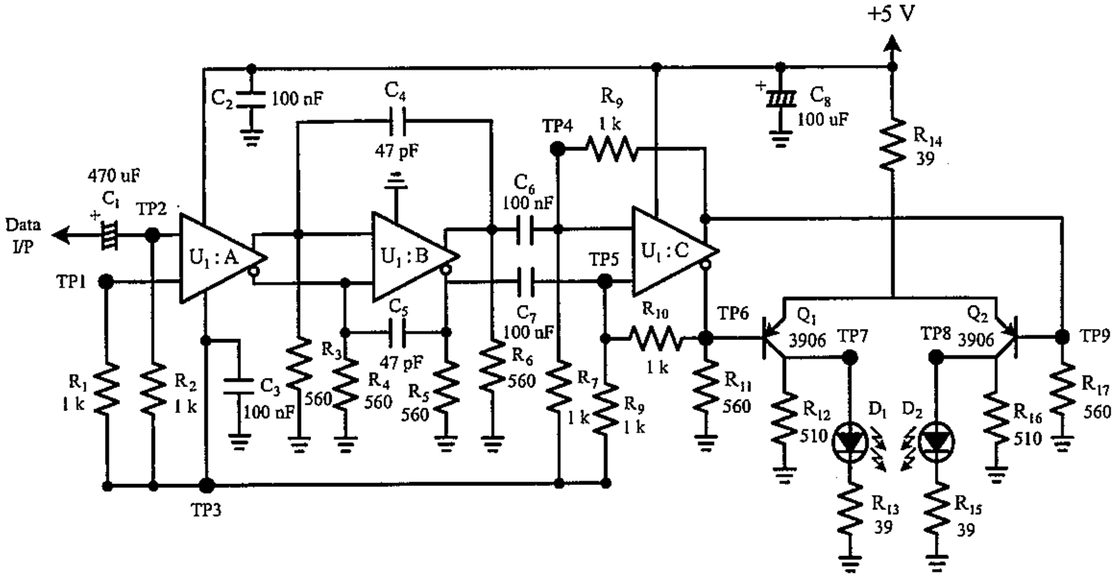


Figure 2-6 The circuit diagram of a 1550 nm optical fiber transmitter.

(2) Receiver

Figure 2-7 is a 1550 nm receiver. The biggest difference of it, comparing to Figure 1-4 in the former chapter, is that the facility in Figure 2-7 uses a differential structure to receive data. The advantage of a differential structure is that it efficiently presses syntype disturbances. In Figure 2-7, MC 10116 amplitude magnifier IC is also used to enlarge received amplified signals, so that received signals would be capable of driving the amplitude magnifier consisted of transistors Q_1 and Q_2, to ensure the accuracy of received data.

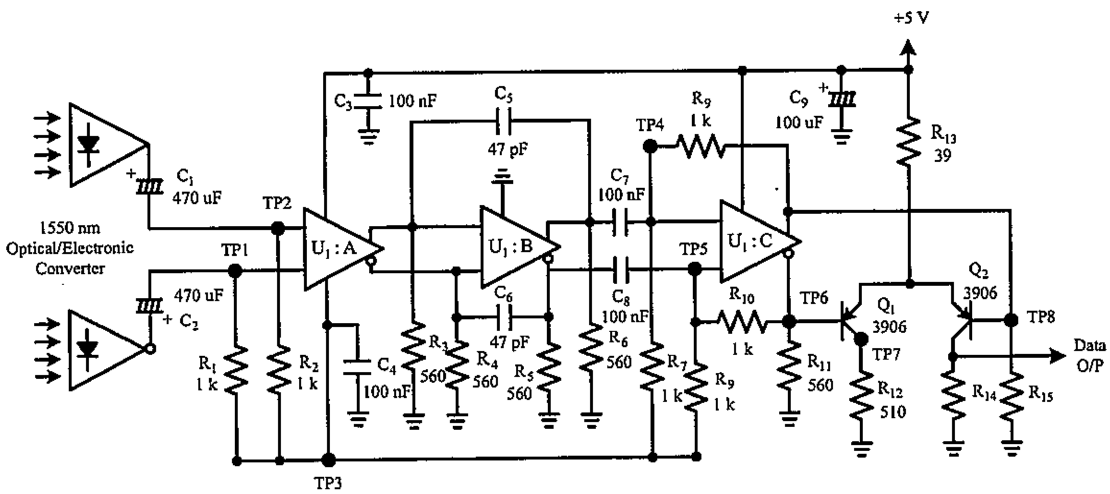


Figure 2-7 The circuit diagram of a 1550 nm received signal receiver.

III. Experiment Items

Experiment 1: The Transmitting Circuit of 1550 nm

1. Assemble the 1550 nm optical fiber transmitter shown as Figure 2-6, or refer same assembly to the OFS2-2 in the models of ETEK OFS-9500-02.
2. Enter a TTL wave with 5 V amplitude, 50% working circle and 10 kHz frequency, at the digital signal input end of OFS2-2 (Data I/P). Use optical fibers to connect OFS-01 and OFS-02 models respectively.
3. Use the oscilloscope to observe the input end of electrode base bias (TP3) on OFS2-2, and record the observed outcomes in table 2-1.
4. Use the CH1 and CH2 on the oscilloscope at the same time to observe input end of Level-1 phase non-reverser (TP1) as well as the input end of Level-1 phase reverser (TP2), and record the observed outcomes in table 2-1.
5. Use the CH1 and CH2 on the oscilloscope at the same time to observe input end of Level-3 phase non-reverser (TP4) as well as the input end of Level-3 phase reverser (TP5), and record the observed outcomes in table 2-1.
6. Use the CH1 and CH2 on the oscilloscope at the same time to observe input end of Level-3 phase non-reverser (TP6) as well as the input end of Level-3 phase reverser (TP9), and record the observed outcomes in table 2-1.
7. Use the CH1 and CH2 on the oscilloscope at the same time to observe both electrode collecting ends of transistor Q_1(TP7) as well as transistor Q_2(TP8), and record the observed outcomes in table 2-1.
8. Repeat Step 3 to Step 7 following the input signals shown in table 2-2, and record the observed outcomes in table 2-2.

Experiment 2: The Receiving Circuit of 1550 nm

1. Assemble the 1550 nm optical fiber receiver as shown in Figure 2-7, or refer same assembly to the 1550 nm receiving circuit shown in OFS1-2, in the models of ETEK OFS-9500-01. Also, assemble the 1550 nm optical fiber transmitter

shown as Figure 2-6, or refer same assembly to the OFS2-2 in the models of ETEK OFS-9500-02.

2. Enter a TTL wave with 5 V amplitude, 50% working circle and 10 kHz frequency, at the digital signal input end of OFS2-2 (Data I/P). Use optical fibers to connect OFS-01 and OFS-02 models respectively.

3. Use the oscilloscope to observe the input end of electrode base bias (TP3) on OFS1-2, and record the observed outcomes in table 2-3.

4. Use the CH1 and CH2 on the oscilloscope at the same time to observe input end of Level-1 phase non-reverser (TP1) as well as the input end of Level-1 phase reverser (TP2), and record the observed outcomes in table 2-3.

5. Use the CH1 and CH2 on the oscilloscope at the same time to observe input end of Level-3 phase non-reverser (TP4) as well as the input end of Level-3 phase reverser (TP5), and record the observed outcomes in table 2-3.

6. Use the CH1 and CH2 on the oscilloscope at the same time to observe input end of Level-3 phase non-reverser (TP6) as well as the input end of Level-3 phase reverser (TP8), and record the observed outcomes in table 2-3.

7. Use the CH1 and CH2 on the oscilloscope at the same time to observe both electrode collecting ends of transistor Q_1 (TP7) as well as transistor Q_2 (Data O/P), and record the observed outcomes in table 2-3.

8. Repeat Step 4 to Step 7 following the input signals shown in table 2-4, and record the observed outcomes in table 2-4.

IV. Experiment Results

Table 2-1 The measured results of 1550 nm transmitter circuit.

Input Signal Frequencies and Amplitudes	Output Signal Waveforms	
TTL (50 %) @ 10 kHz	TP1、TP2	TP3
	TP4、TP5	TP6、TP9
	TP7、TP8	

Table 2-1 The measured results of 1550 nm transmitter circuit(cont.).

<table>
<tr><th rowspan="2">Input Signal Frequencies and Amplitudes</th><th colspan="2">Output Signal Waveforms</th></tr>
<tr><td>TP1 、TP2</td><td>TP3</td></tr>
<tr><td rowspan="6">TTL (50 %) @ 100 kHz</td><td></td><td></td></tr>
<tr><td>TP4 、TP5</td><td>TP6 、TP9</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">TP7 、TP8</td></tr>
<tr><td colspan="2"></td></tr>
</table>

Table 2-2 The measured results of 1550 nm transmitter circuit.

Input Signal Frequencies and Amplitudes	Output Signal Waveforms	
TTL (33 %) @ 10 kHz	TP1、TP2	TP3
	TP4、TP5	TP6、TP9
	TP7、TP8	

Table 2-2 The measured results of 1550 nm transmitter circuit (cont.).

<table>
<tr><th>Input Signal Frequencies and Amplitudes</th><th colspan="2">Output Signal Waveforms</th></tr>
<tr><td rowspan="6">TTL (33 %)
@ 100 kHz</td><td>TP1 、TP2</td><td>TP3</td></tr>
<tr><td></td><td></td></tr>
<tr><td>TP4 、TP5</td><td>TP6 、TP9</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">TP7 、TP8</td></tr>
<tr><td colspan="2"></td></tr>
</table>

Table 2-3 The measured results of 1550 nm receiver circuit.

Input Signal Frequencies and Amplitudes	Output Signal Waveforms	
TTL (50 %) @ 10kHz	TP1、TP2	TP3
	TP4、TP5	TP6、TP8
	TP7、Data O/P	

Table 2-3 The measured results of 1550 nm receiver circuit (cont.).

Input Signal Frequencies and Amplitudes	Output Signal Waveforms	
TTL (50 %) @ 50 kHz	TP1 、TP2	TP3
	TP4 、TP5	TP6 、TP8
	TP7 、Data O/P	

Table 2-4 The measured results of 1550 nm receiver circuit.

Input Signal Frequencies and Amplitudes	Output Signal Waveforms	
TTL (33 %) @ 20 kHz	TP1 、TP2	TP3
	TP4 、TP5	TP6 、TP8
	TP7 、Data O/P	

Table 2-4 The measured results of 1550 nm receiver circuit (cont.).

Input Signal Frequencies and Amplitudes	Output Signal Waveforms	
TTL (33 %) @ 100kHz	TP1 、TP2	TP3
	TP4 、TP5	TP6 、TP8
	TP7 、Data O/P	

V. Problems Discussion

1. Please explain the emitted forms of FP laser and LED?
2. What are the advantages and disadvantages of FP laser and LED? What are the different between FP laser and LED?
3. What components consist of the glass fibers? How many energies will be consumed in each ten kilometer?
4. According to the transmission mode, which the types of the optical fibers can be classified ? and what are their characteristic?
5. In accordance with the various types of fabricated material, which the types of the optical fibers can be classified ?
6. Please draw the basic structure of optical fibers and explain the fabricated materials.
7. What are the purposes of Q_1 and Q_2 in the differential circuit in figure 2-6?