### 3.13 Principle of EDFA (Erbium-Doped Fiber Amplifier)

**Objective:** Study the principle of EDFA operation and measure the amplification characteristics of an EDFA

#### List of components

| Handheld laser source (1310 nm/1550 nm) | 1 |
|---|---|
| EDFA module with AC adapter             | 1 |
| Handheld laser optical power meter      | 1 |

#### Theory

### **EDFA** fundamentals

1) EDFA and its application

An optical amplifier is a device that amplifies an optical signal directly, without the need to first convert it to an electrical signal, then amplify it, and finally reconvert it to an optical signal. Optical amplifiers have become the essential parts in all-optical communications. Erbium-doped fiber amplifiers (EDFAs) are optical amplifiers that use an Erbium-doped optical fiber as a gain medium to amplify an optical signal. EDFAs have been widely used in long-haul fiber optic systems. This technology is a milestone in optical fiber communication.

2) The basic structure and working principle of an EDFA

The main parts in an EDFA include Erbium-doped fiber, pumping laser, WDM and optical isolator. Erbium-doped fiber is the active gain medium. Its optimum length is subject to the Erbium ion concentration. The pumping source is a high power semiconductor laser diode whose wavelength is at 980 nm. The WDM integrates the signal and pumping light into the Erbium-doped fiber. The optical isolator is uni-directional and isolates the signal light from being influenced by the reverse waves. EDFAs are either unidirectional or bi-directional.

There are usually three types of EDFA for different applications: pre-amplifier, in-line amplifier, and booster amplifier. A pre-amplifier usually has a high gain of 20~30 dB to amplify very weak signal level down to -32 dBm, and it is normally positioned at the end of a transmission line; an in-line amplifier operates in the middle of an optical link, and it features medium to low input power, high output power, high optical gain, and a low noise figure; a booster amplifier is used at the beginning of the line with input levels around 0 dBm and gain of 9 to 15 dB.

3) The main specifications of EDFA

The EDFA used in this experiment is a booster with active gain control so a stable output level of 12.7 dBm is achieved. The pumping lasers in the EDFA module are turned on only after a signal level within the input power range is received by the EDFA and then the power indicator turns from green to orange; otherwise, the power indicator on the EDFA module would be in green color, meaning no optical signal or no sufficient input optical power is received by the EDFA. Alternatively, an EDFA can be used as a broadband ASE light source by pumping the Erbium fiber with 980-nm laser light without 1550 nm optical input. For this EDFA, one needs to input 1310-nm laser light to the EDFA to turn on the pumping lasers, the output signal from the EDFA will be broadband ASE light.



Figure 29 Schematic diagram of EDFA

#### Experiment

#### Measure the amplification characteristics of an EDFA

Refer to Figure 29:

1). Measure the output power of the light source as the input power,  $P_{in}$ , of EDFA with the handheld power meter in unit of dBm.

- 2). Measure the output power,  $P_{out}$ , of EDFA with the handheld power meter in unit of dBm.
- 3). Substitute the measured results into equation (1) to get the EDFA amplification in dB

$$\alpha = P_{out} - P_{in}(dB) \tag{13-1}$$



Figure 30 Photo of experimental setup for EDFA characterization

# 3.14 Transmission of analogue audio frequency signal in free space

**Objective**: Understand the basic structure of free-space analogue communication and implement the transmission of analogue audio frequency signal in free space.

#### List of components

| 650 nm transmitter                     | 1 |
|--|---|
| Audio detector (with built-in speaker) | 1 |
| DC regulated power supply              | 1 |
| Radio                                  | 1 |
| Post holder                            | 2 |

# Introduction of free space optical communication

In contrast to wired optical communication in which fiber is used as transmission channel, atmosphere is used transmission channel in free space optical communication system (FSO). There is expensive cable installation in FSO, which has potential in space communication. In FSO, the signal to be transmitted is either digital or analogue. Signal is modulated either directly or externally.

#### Experiment

# Implement the transmission experiment of analogue audio frequency signal in free space

Refer to Figure 31:

- 1) Mount the 650 nm transmitter and audio decoder onto the two post holders.
- 2) Set a distance between the transmitter and the decoder about 50 cm. Align the laser of the transmitter into the decoder head.
- 3) Plug the 3.5 mm earphone plug of the transmitter into the earphone socket of the radio (or any other audio sources).
- 4) Turn on the power and make fine adjustments to the transmitter and decoder if necessary.
- 5) Now the sound from the radio should be heard from the built-in speaker.
- 6) Block the laser beam with hand, no sound should be heard from the speaker; remove hand, the sound should be heard again from the speaker, indicating that the audio signal is indeed modulated by the optical signal (laser beam) in free space.



Figure 31 Schematic of transmission of analogue audio frequency signal in free space



Figure 32 Photo of experimental setup

# 3.15 Transmission of video signal through optic fiber

**Objective:** Understand the basic structure of a fiber optic video transmission system and implement the transmission of video signal through an optic fiber.

# List of components

| Fiber optic transceiver                | 1 |
|--|---|
| Fiber optic receiver                   | 1 |
| DC regulated power supply (Dual 5 VDC) | 1 |

| 3 m single-mode patch cable | 1 |
|-----------------------------|---|
| CCTV camera                 | 1 |
| LED display                 | 1 |
| BNC cable                   | 2 |
| 2-pin push-pull cable       | 2 |

#### Introduction of fiber optic video transmission

In previous experiment, the transmission of analogue audio signal in free space is demonstrated. While it has features of low cost and simple structure, there are some disadvantages that limit its applications in transporting high-resolution video at higher bandwidths for a long distance in commercial, industrial and residential sectors. In the current age of continuously develop networks for global communication, fiber optic transmission is experiencing its prime. Fiber video transmission not only enables efficient transport of digital data but also allows for clearer, faster, more efficient communication.

In a fiber optic video transmission system, the signal to be transmitted is either analogue (CCTV video signals: NTSC, PAL, SECAM) or digital (HD video signals: HDMI, HD-SDI, HD-TVI, HD-CVI, and AHD).

# Experiment

# Implement the transmission experiment of video signal through an optic fiber

Refer to Figure 33:

- 1) Place the dual 5 VDC power supply, CCTV camera, transmitter, receiver, and LCD display onto the experiment desk.
- 2) Connect the 2 outputs of the 5 VDC power supply to the input 5 VDC ports of the transmitter and the receiver respectively.
- 3) Connect the 12 VDC output of the transmitter to the 12 VDC input of the camera using a 2pin push-pull cable.
- 4) Connect the 12 VDC output of the receiver to the 12 VDC input of the LCD display using a 2-pin push-pull cable.
- 5) Connect the video output of the camera to the input of the transmitter using a BNC cable.
- 6) Connect the FC output of the transmitter to the FC input of the receiver using a 3 m singlemode patch cable.
- 7) Connect the video output of the receiver to the input of the LCD display using a BNC cable.
- 8) Double check correctness of all wire and cable connections and turn on power supply.
- 9) Now live video will be displayed on the LCD screen.



Figure 33 Schematic of transmission of video signal through optic fiber



Figure 34 Photo of experimental setup