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	1
Handheld laser optical power meter	1
DC regulated power supply	1
Mating sleeve	2

Theory

The 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.

3) The main specifications of EDFA

   A. Gain saturation
   It is an important characteristic of an EDFA. The gain coefficient decreases as the signal power level increases. When the optical power, P, exceeds the saturation optical power P_{sat}, the gain becomes saturated.

   B. Noise effect
   EDFA exhibits lower noise. Signal-to-noise ratio (OSNR) has been much improved so that it is widely used as a pre-amplifier to obtain higher sensitivity.

   C. Frequency response
   EDFA's transmission wavelength spectrum is over 35 nm, corresponding to 4300 GHz

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 the EDFA with the handheld power meter

2). Measure the output power, P_{out}, after the 2nd 1550 nm isolator with the handheld power meter

3). If necessary, measure the insertion losses of both 980/1550 nm WDM and 1550 nm isolator at 1550 nm in terms of dB, as L (dB)

4). Substitute the measured results into equation (1) to get the EDFA amplification in dB

$$\alpha = 10 \times \log \frac{P_{out}}{P_{in}} (dB) + L\,(dB) \qquad (13\text{-}1)$$

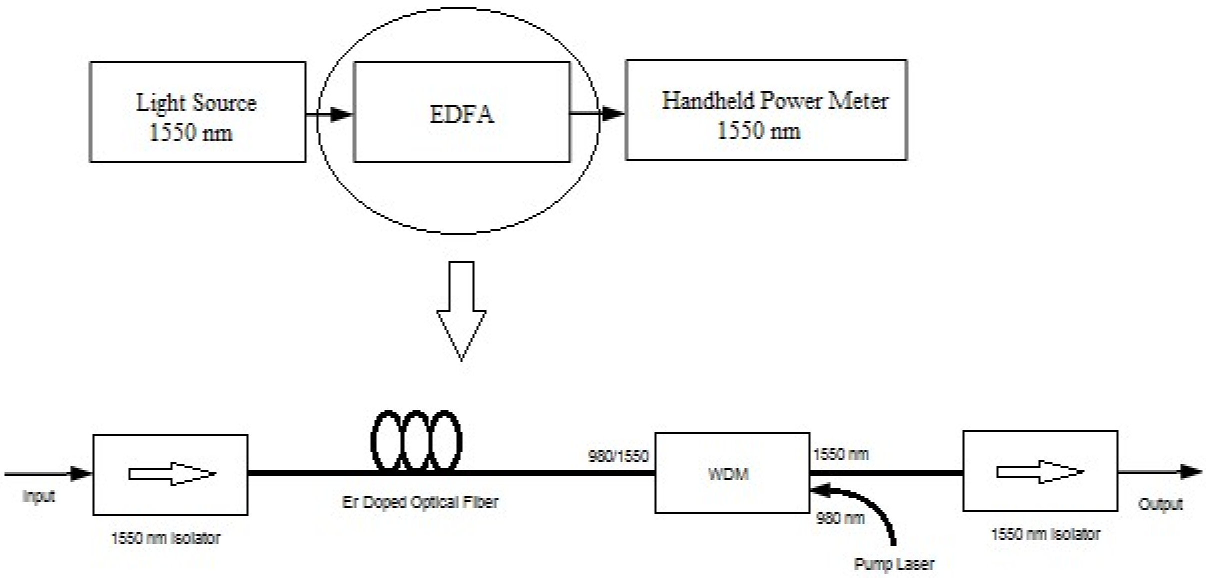

Figure 29 Schematic of EDFA

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	1
DC regulated power supply	1
Speaker	1
Radio	1
Post holder bench	1
2-pin Push-pull cable	1

Theory

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) Place the 650 nm transmitter and audio decoder onto the post holder bench.
2) Align the transmitter into the detector head and lock both items in place.
3) Plug the radio into the transmitter and the speaker into the decoder.
4) Turn on the power and make fine adjustments to the transmitter if necessary.
5) Now the sound from the radio should be heard from the 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.

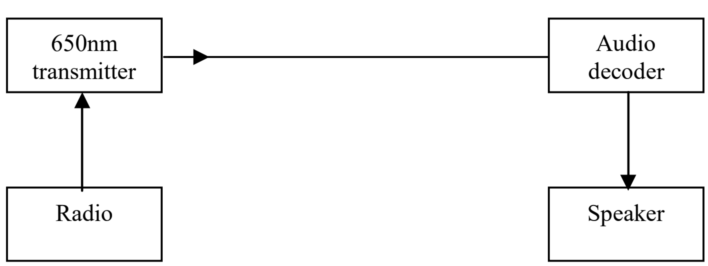

Figure 31 Schematic of transmission of analogue audio frequency signal in free space

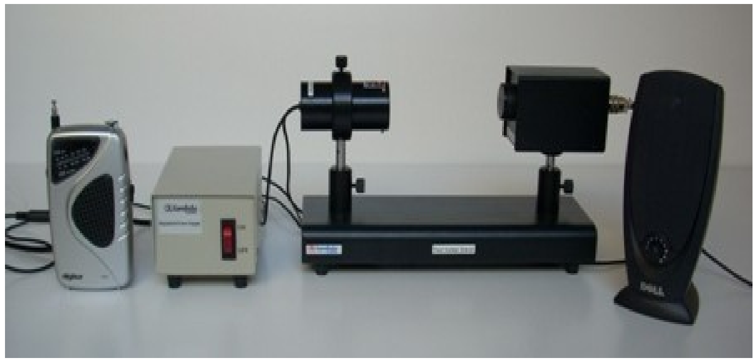

Figure 32 Photo of experimental setup