Principle and application of amplifier of fiber on fiber communication

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Abstract. As the most widely used and the most reliable way of communication in the world today, the development of optical fiber communication will inevitably affect the world. As an important component of fiber communication system, the development of fiber amplifier directly affects the development of fiber communication. The fiber amplifier is divided into semiconductor fiber amplifier, mixed with rare earth element fiber amplifier and nonlinear fiber amplifier. This paper aims to study the principle, function and equipment of the fiber optic amplifier. Some limitations and prospects for the future are also proposed.The principle, function and limitation of erbium-doped fiber amplifier are emphasized. It is a summary of the development of fiber amplifier in recent years, and it is convenient for other scholars to find and study the data of fiber amplifier. This paper summarizes the development of fiber amplifier in recent years, and explains the basic principles of fiber amplifier, so that other scholars to find the data of fiber amplifier, convenient for other scholars to study.

Keywords: Optical fiber amplifier (OFA), erbium-doped fiber amplifier (EDFA), principle of OFA.

1. Introduction

As an optical device based on optical fiber technology, optical fiber amplifier is one of the necessary module in the field of photo-communication and laser, which can amplify and output the input optical signal. Due to the loss of optical fiber and optical fiber, the distance of transmission of any optical fiber communication system is restricted by the wastage or dispersion. Light-pulse signals are transmitted in optical fibers [1]. With the increase of transmission distance, the fiber loss leads to the gradual decrease of the pulse amplitude, and the energy of the optical signal gradually reduces the fiber dispersion makes the pulse width widen in time, producing waveform distortion. In the long-distance optical fiber transmission system, a repeater must be set up at the appropriate position of the line to process and amplify the attenuated and distorted optical signals. There are two ways to solve the problem, one is to reduce the transmission loss of optical fiber. At present, low loss optical fiber with loss can be produced. Second, it is to add a relay station to amplify, repair and regenerate the optical signal at a certain distance and attenuation to a certain extent [2].Optical fiber amplifier, a kind of optical device that can amplify the power of optical signal, is a new type of all-optical amplifier to realize amplifying signal. According to previous scholars, according to the use of amplifiers on optical fiber lines, optical fiber amplifiers are generally divided into three types, which are pre-amplifiers, power amplifiers and relay amplifiers. Compared with semiconductor amplifiers, OFA has fewer steps such as photoelectric conversion and can directly amplify light. Because of this characteristic, OFA is well suited as a repeater in long-distance fiber optic communications. Fiber optic communications have great transmission distances, even hundreds of miles. Because of its low bit error rate, it is known as the most reliable telecommunications technology. Optical transmission is when light can transmit information over a cable. The role of optical fiber amplifiers is to compensate for the losses generated in optical fiber communication. DFA is a doped optical fiber amplifier, which can be doped with rare earth materials such as bait (Er^{3+}) to make optical amplifiers [3]. In 1985 by the British university of Southampton D Payne scientists found erbium doped fiber as 1550nm wavelength area of optical amplifier, and developed the first with 25dB small signal gain erbium doped fiber amplifier, later after the efforts and improve the scientists, developed into today's large number of commercial used for all kinds of optical fiber communication system of EDFA,

greatly promoted the development of optical fiber system application, can say EDFA, the emergence of is a big change in optical fiber communication technology [4].In recent years, fiber amplifier is widely used in fiber communication. Optical amplifier is an important part of optical fiber communication system, so its high-performance technical change has become urgent [5]. At present, the mainstream optical amplifiers include erbium-doped fiber amplifier (EDFA), distributed Raman optical amplifier (DRA), semiconductor optical amplifier (SOA), etc. EDFA has high output power, high gain, low noise, widely used in backbone network, OTN, PTN; DRA has wide gain, moderate, low efficiency, but very low effective noise, even negative value, can greatly improve the transmission performance of the system, mainly used in long distance and long span optical transmission system; SOA can enlarge the bandwidth that EDFA cannot enlarge, but the noise is slightly larger than EDFA, the output power is not high, mainly used in 5G, DCI, data link acquisition system, high-speed optical modules.

According to previous research, optical amplifiers can be divided into two types. One is an optical fiber amplifier and the other is a semiconductor amplifier. Praseodymium doped fiber amplifiers, Raman amplifiers and erbium-doped fiber amplifiers are also known as fiber amplifiers. The most widely used in the world today is the erbium-doped fiber amplifier, which operates at 1550nm wavelength. The praseodymium-doped amplifier can work at 1310nm wavelength, but it is still in the laboratory research stage due to the unsatisfactory conversion efficiency. Raman amplifier is a new type of amplifier commercialized in recent years, which is mainly used in the need of distributed amplification. Semiconductor optical amplifier structure is small, convenient integration, has been favored by many people. However, because the polarization effect is not ideal, there has been no large-scale commercialization Erbium-doped fiber amplifier has been widely used in the market. Therefore, this paper uses an erbium-doped fiber amplifier as an example to study its working principle and its role in human production and life.

2. Basic Descriptions

Photo-communication is a communication type with light wave as the carrier frequency and optical fiber as the transmission medium. Without optical communication, there would be no today's information age. The smartphones we use every day are highly dependent on light transmission, which provides a pipeline for the huge amount of traffic received by large numbers of 4G / 5G base stations. The spectrum range of the carriers varies in different communication systems. The optical fiber communication system is located in the high frequency spectrum area, its wavelength is 0.8~1.8 μ m near infrared, the frequency is 167 ~ 365 THz, and the microwave frequency is 0.3 ~ 3 THz, which determines that the optical fiber communication is a communication system with a wider bandwidth than microwave communication and satellite communication. Currently, the researchers achieve single-carrier rates of up to 1.52 Tb/s on a standard 80km single-mode fiber. In industry, the latest 10 GPON provides up to 10 Gb/s up and down symmetry rates, with the delay reduced to less than 100 μ s and the number of connections increased by more than 100 times, transforming the "fiber to the home" mode into "light connecting everything".

Optical fiber is a concentric cylinder. Outside the cylindrical core are concentric cylindrical cladding with different refractive indices. The function of the fiber core is to conduct the light wave, and the function of the cladding is to close the light wave in the optical fiber for propagation. In an optical fiber (uniform refractive index fiber), light is transmitted forward by the full reflection on the boundary of the core and cladding. There are two kinds of light that shoot into the optical fiber: one is the light through the axis of the optical fiber core, called the meridional ray, the meridional ray in the optical fiber along the zigzag broken line forward. The other is the oblique light, which does not cross the axis of the fiber core, from the end of the optical fiber, the propagation trajectory of the oblique light is a polygonal folded line. It is known that the refractive angle increases with the incidence angle as the light bursts into the interface of the photo-hydrophobic medium from the light-dense medium. When the angle of incident reaches a critical value, the Angle of refraction is 90°. At

that time, there is no refracted light, and all the light is reflected. This phenomenon is called total reflection. Due to this total reflection characteristic of optical fiber, it is widely used in the field of information propagation [6].

3. Function

Optical fiber amplifier technology is the incorporation of rare earth elements that can produce laser into the optical fiber core, and the amplification of the passing optical signal through the DC light excitation provided by the laser. The traditional optical fiber transmission system uses light-electricity-optical regeneration repeater. This relay equipment affects the stability and reliability of the system. In order to remove the above conversion process and magnify and transmit the signal directly on the optical road, it is necessary to use an all-optical transmission repeater to replace this regenerative repeater.

The basic model of EDFA is shown in Figure 1 for the constituent spectropath portion and circuit portion of , EDFA. The optical circuit includes pump light source, erbium-doped fiber (EDF), optical separator, photosynthetic wave device (WDM), optical coupler; the circuit circuit includes microprocessor, controller, detector, power supply, alarm and protection circuit.The most critical and basic unit of the amplifier is the er-doped fiber, which is powered by a pump source. Encourage the er-doped fiber to induce the erbium-doped fiber and release the energy to amplify the optical signal. The incentive mode is divided into the former mode, the latter mode and the double mode generally adopt the former incentive mode, but the two-way incentive mode should be used in the case of the special need for high gain and high output.Photosynthetic wave devices are used to couple er-doped fibers to energy sources. The light separator is used to prevent the amplifier from producing self-excited oscillations. Optical coupler provides a part of the optical signal to the optical detector to achieve real-time monitoring of the operating state of the amplifier. The microprocessor can monitor the optical input and adjust the operating state of the pump light source to realize automatic temperature control and automatic power. control.

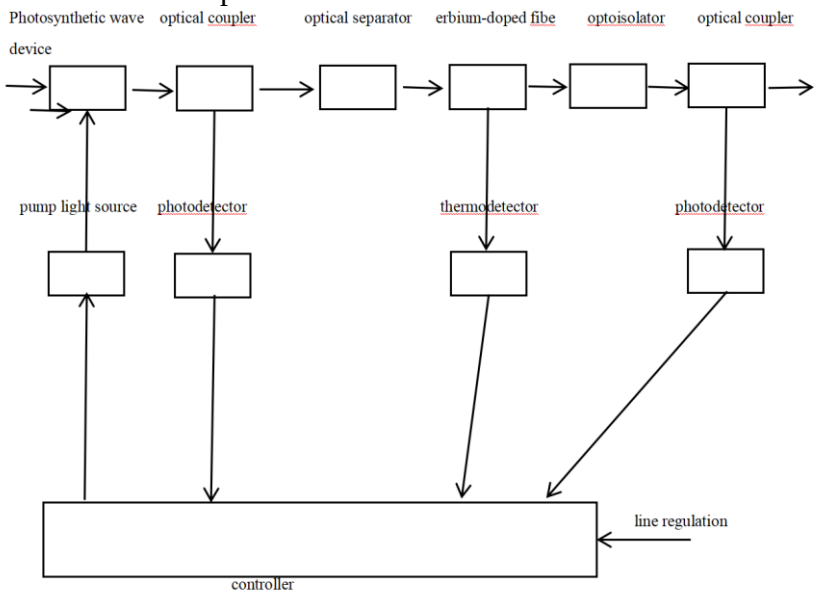


Figure 1. The basical model of EDFA

The stimulated amplification principle of erbium-doped fiber The energy level of Er 3 + in er-doped fiber is a three-level system with Er 3 + at the ground state level of 4I15 / 2. When pumped at wavelengths of 532nm, 667nm, 800nm, 980nm, or 1480 nm (to avoid excited absorption (ESA) by using 980nm or 1480nm semiconductor laser (LD) now the most widely used pump is 980nm LD.) They transition to high levels E2 and E1 respectively from Er 3 + at high levels E2 to 4 I 3 / 21 / 2 metastable level E1 by nonradiation. The lifetime of Er 3 + for up to 10ms can accumulate a large number of Er 3 + to form particle number inversion between 4I13 / 2 and the ground state level of

4I15 / 2. When the photon with the wavelength of 1550nm is injected, a strong stimulated radiation can be amplified. The Er 3 + in the metastable level returns to the ground state level to realize the amplification of the light signal. The principle of optical signal amplification is shown in Figure 2. [7].

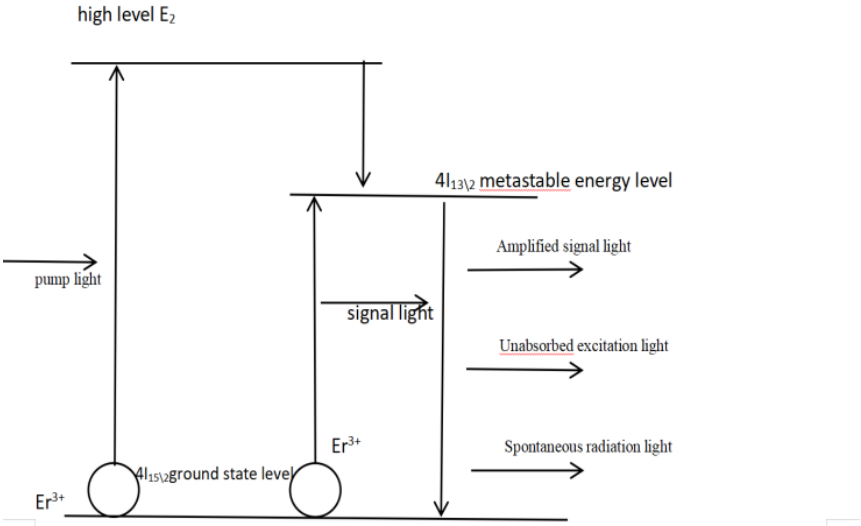


Figure 2. Principle of optical signal amplification

As one of the key components of photo-communication, er-doped fiber amplifier (EDFA) has been driven to the direction of integration, miniaturization, multifunctional and low cost in the evolution of various networks and applications. In the background of the rapid development of EDFA industry, many manufacturers have also launched Hybrid integrated devices to realize the competitive advantage of EDFA technology. Hybrid optical passive device is the most important functions in EDFA, optical separator (Isolator), wave division multiplexer (WDM), gain flat filter (GFF), coupler (Coupler), TAP PD (spectral detector), integrated two or more than a combination of functions in a device, realize the same function premise greatly reduce the size of the device and reduce the cost.

4. Application and device

The development of fiber amplifier has been studied many equipment, it has many categories according to different uses.Like Long Range Fiber Optic Ampifiers, can be used for precise positioning and water quality liquid detection(Details are shown in Figure 3); Or like a radiating hard mid-power fiber amplifier for analog satellite laser communication links and high speed digital [8], as shown in figure 4; Here is another high-power, single-frequency, single-chip fiber amplifier that will be used by the next generation to detect gravitational waves [9],as shown in Figure 5; There are still many of the same types, too, and scientists and companies will still develop new fiber amplifiers to meet human needs. So this article will not be repeated here.



Figure 3. Universal fiber-optic amplifier.

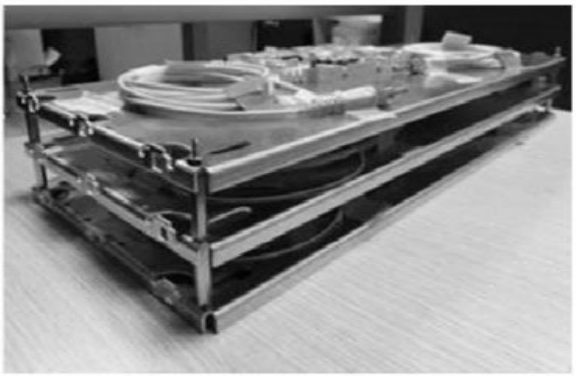


Figure 4. EDFA optical engines mounted suitable for transportation to the test-house.

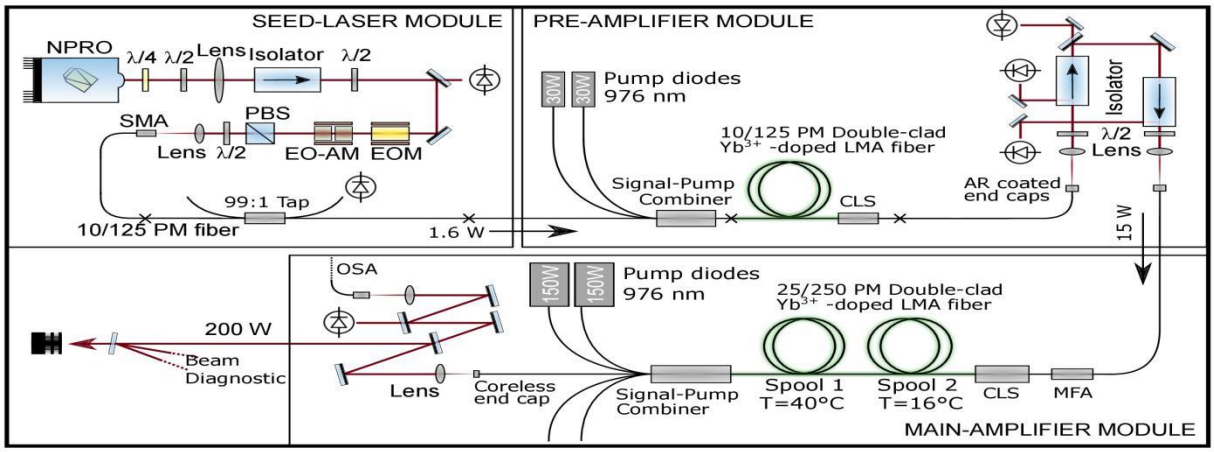


Figure 5. Setup diagram of the enginering fiber amplifier protype

5. Limitations & Future outlooks

5.1. Limitations

Although fiber amplifier has been used in fiber communication for many years, it still has some limitations. Studies have shown that optical preamplifiers cannot approach the optimal performance at data rates below a few Gbit/s, due to problems such as global inversion parameters, source laser stability, polarization effects, and input coupling losses [10]. Like the most widely used erbium-doped fiber amplifier, there are still some limitations. For example, temporal deformation of nanosecond laser pulses in the amplification layer of a two-stage erbium-doped fiber amplifier operating at saturation [11]. Like the Raman fiber amplifier, it has the limitations of insufficient gain bandwidth 'low output gain' uneven output gain and so on.As for the semiconductor optical amplifier, the noise is slightly larger than EDFA, and the output power is not high.

5.2. Future outlooks

Currently, optical fiber communication has entered a new period of involving a wide range of technology renewal is more difficult and wider influence is bound to have a important impact on the whole telecom industry. OFA's evolution and development results will largely determine the telecommunication network and information. The future pattern of industry will also have a huge impact on social and economic development.

6. Conclusion

Optical fiber amplifier is an important equipment in optical fiber communication system, which can amplify and transmit optical signals. This paper introduces the development history of optical fiber amplifier, tells its principle, and introduces the functions and limitations. By introduces the principle of EDFA and the equipment. To make readers understand the development process of optical fiber amplifier in recent years. Also, EDFA is used as an example to indicate the temporal deformation of the nanosecond laser pulse in the amplified layer at saturation. In the end, the fiber amplifier industry is discussed: the development of OFA will greatly affect the development of the photo-communication industry. The 1550nm-1600nm band tends to be saturated, and the fiber amplifier research industry needs to make new technological breakthroughs, to find new available bands to meet the needs of human life.

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