Journal of Computational Science & Engineering 12 (2014) 452-456

Journal of Computational Science & Engineering

Available at http://www.asocse.org ISSN 1710-4068

Research on the Key Technology of Space Laser Communication Transmission

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Article Information

Article history:
Received 15 May 2014
Revised 8 June 2014
Accepted 9 June 2014
Available online 9 June 2014

Keywords:
Wireless Laser Communication
High speed
High power

Abstract

Because the space laser communication has the advantages of high speed, security and good, it is used in all kinds of platform more and more widely. This paper presents and analyses the key technology which needs to be solved to realize high speed space laser communication, and describes the way to solve the key technology.

1. Introduction

Space laser communication, which has the advantages of large information capacity, good confidentiality, anti-interference capability, has become a research focus in the world. After decade's development, the current space laser communication has made tremendous progress. The static and dynamic experiments have been made for some space laser communication system load in multiple platforms. With the rapid the development of Optoelectronic Technology, the space laser communication system transmitting power, the modulation rate and other technical indicators are high increasingly. The other application platforms are more and more widely. The development trend of space laser communication system in the future will be applied in the field of satellite communications and deep space exploration. The key technology of space laser communication system transmitting unit which needs to be solved mainly large output power and high speed modulation in order to satisfy the requirement of space optical communication system communication for far distance, more and large information capacity.

2. Method and technology

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Laser modulation is divided into inner modulation and external modulation. Inner modulation is to load the modulation signal in the process of laser oscillation. The inner modulation device has the advantages of smaller volume and simple control. But the output power is low. And it is limited by some specific performance of the laser itself easily. Especially, when the modulation rate reaches a constant speed, it will produce the chirp. Namely the pulse width becomes wider. The serious chirped phenomenon will cause the entire communication system failure. The parameters of the laser itself impact on the external modulation relatively small. And the modulation rate is very high.

In high speed space laser communication, the external modulator must have enough modulation bandwidth, high saturation power and low driving voltage. And the low chirp, high extinction ratio, low polarization dependence and low insertion loss are the important influence factors need to be considered for external modulation. EAM has the advantage of low driving voltage, small volume. It is easy to be used with lasers, optical detector, amplifier and other optical devices. The modulation bandwidth may be up to 40-50GHz; the modulator output may be up to 5.5dBm; low driving voltage is the 1V (peak to peak); modulation region length is 63Lm; the extinction ratio can reach 15dB. These values meet the application of high speed modulation. EAM is improved using the following technique.

2.1 Using traveling wave electrode

The external signal electrode structure is one of the factors limiting the EAM modulation rate. Using the lumped constant electrode, the modulation rate will depend on the geometry of lumped electrode. The size is inversely proportional with the PN junction capacitance. Using TW electrode, the modulation rate will depend on the microwave loss inside the electrode and the propagation velocity matching degree between the light and the high frequency electrical signals. To realize high speed modulation for the EAM, the traveling wave electrode structure is crucial. It must gain the wider modulation bandwidth while the modulation efficiency is not affected. Using traveling wave electrode for EAM, the interaction length become short and the bandwidth avoids being limited by the CR effectively, the final realization of high speed modulation.

2.2 Using FCB Technology

Another important factor to realize high speed modulation for EAM is the mounting structure of modulator chip. The connection between the EAM chip and signal transmission line is usually to rely on the wire bonding technology. But the electrical properties of EAM in the high frequency region may be reduced because of the parasitic inductance for pressure welding wire. Using the FCB technology, it is used to reduce the parasitic inductance during EAM installation, and make the interconnection length between the electric transmission line and the EAM chip is reduced to the shortest.

2.3 The optimization of multiple quantum well structure

The EAM adopts the optimization multiple quantum well (MQW) structure. It can make the EAM have the advantages of small volume, low driving voltage, high output power, small polarization sensitivity, just like the MZ and EA modulators. Compared with the traditional deep etched ridge waveguide structure, InAlAs MQWEA modulator and heterogeneous hidden buried structure of InGa As show the good comprehensive properties. Especially they enhance the ability to transmit optical power. It is suitable for high speed applications system.

2.4 The chirp inhibition

The wavelength chirp phenomenon in EAM is caused by changing the wavelength. In order to eliminate or reduce the influence of chirp, the

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modulator design, production, application and other aspects can be considered. It is one of the most important measure that is to use the MQW structure make the optical absorption layer dependent variable of the multiple quantum well be in the best state and the optical absorption layer material component of quantum well be optimized. In addition, the external voltage is closely related with chirp of EA modulator. There is an inverse relationship between them.

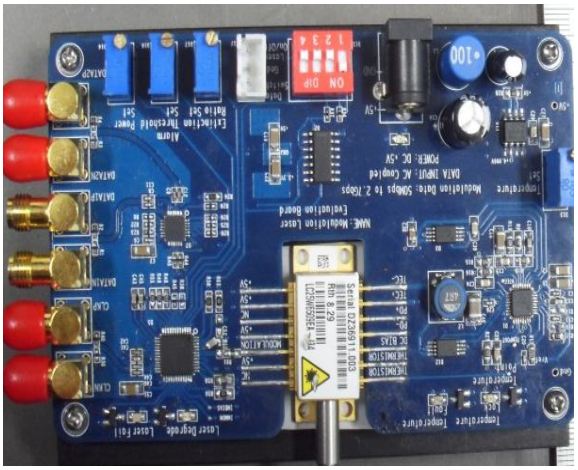

Fig.1 High speed modulation emission source

3. High power optical amplification technology

The laser power of communication transmitting unit is 2W and the wavelength is 1550nm. After realizing the high speed laser modulation emission source, the low power and high speed optical signal needs to be amplified by corresponding high gain optical amplification technology. Laser amplification technology with the wavelength 1550nm is mainly the erbium doped fiber amplifier (EDFA). But the output power of EDFA is about 23dBm (200mW). It is far less than the value required by the system. So it is necessary to conduct the innovation research of optical amplification technology. As shown in Figure 2, the output power of high speed modulation laser emission source is 1mW. After optical amplification, the output power is 2W, the gain is 33dB.

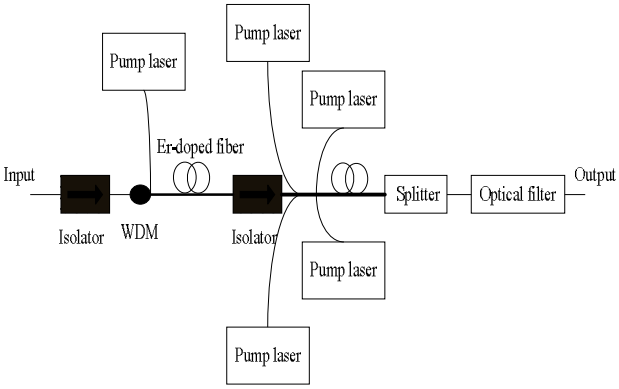

Fig. 2 Schematic diagram of two stage optical amplification

The first stage is a typical erbium-doped fiber amplifier system. The signal light and pump light go through a wavelength division multiplexer into the single-mode erbium doped fiber. The forward pump mode is used. At the output and input of signal have the isolator avoiding the echo effect. The optical isolator is to suppress the light reflection and makes the optical amplifier work steadily. The isolation should be better than 40dB, and the insertion loss is low. The pump laser adopts 980nm wavelength semiconductor laser. The erbium doped fiber amplifier technology serves as the first stage in the two stages optical fiber amplifier. Taking into account the laser safety and fiber nonlinearities, the output power is limited to 22dBm (160mW) below.

The second stage optical amplifier is the key technology to realize optical fiber amplification with high gain. The erbium-ytterbium co-doped double-clad fiber and the efficient side pumping technology are used to achieve high gain optical power amplifier. In the second stage optical amplifier, there are also a pump laser, optical coupler, isolator and filter. The output signal of the first stage amplifier is used as the second stage amplifier input.

3.1 The erbium-ytterbium co-doped double-clad gain optical fiber

The double-clad structure is the only way to obtain high power in the doped fiber. It is very

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high efficient to use the high power laser diode (LD) pumped fiber amplifier. Because the outer core has great space, the system is not very sensitive with the pump disorders. So it has many advantages in space applications. However, the large outer core space will reduce the absorbed pumping power. And the fiber length needs to increase. In high pump and high modulation rate region, the fiber geometry is not the biggest effect to gain but dopant concentration. Therefore, carefully adjusting the dopant concentration and the outer core space diameter is very important to achieve the desired effect. In the optical fiber of medium doped double-clad structure, the single-mode core is surrounded by multimode region. The pump power can be transmitted easily in this area. The pump light has been absorbed by the medium doped fiber core gradually. The high output power can be achieved. Using the coating technology, the coating reflectivity is lower than the quartz glass, so the waveguide can be obtained in the outer cladding.

The double-cladding technology increases the absorption length, so that the doped medium does not need to very high concentrations or the fiber length does not need to absorb the pump effectively. In the long optical fiber, the absorption of signal wavelength will reduce the amplifier efficiency because the gain must compensate the propagation loss. The long optical fiber is sensitive to cosmic radiation. The radiation can increase the optical absorption, reduce loss, and is proportional to the fiber length. On the other hand, propagation loss mainly depends on the manufacturing process. The loss which is reduced cosmic radiation does not seem affected by dopant concentration. Thus dopant concentration should be increased to ensure the fiber length as short as possible.

3.2 Double-clad fiber efficient pump technology

In the double-clad fiber amplifier, the larger volume dichroic mirrors is used usually in order to make the multimode pump light and single mode signal coupled to the double-clad fiber simultaneously. This mode increases the cost and volume. But the pump light can only go into the double-clad fiber through its two end surfaces. Because the fiber end surface area is limited, the high power laser is not coupled into the double-clad fiber by LD arrays. The end surface is used to pump coupling and can't weld with other optical devices. Only the signal light and the pump light are multiplexed through the dichroic mirrors. That will increase the insertion loss. In addition, the method need use the multidimensional optical fiber regulating system with high precision. And the regulating system drift will affect the system stability. In this paper, the pumping coupler technology is carried out, which the pump light is coupled into the flank of inner cladding in the double-clad fiber.

Fused tapered directional coupler is referred to as the platform beam splitter. Multimode optical fiber fused tapered directional coupler makes many bare fiber and clapping fiber removed the external clapping enwind together. They are heated and melted in high temperature flame. At the same time the fiber is stretched at both ends. The fiber fusion zone becomes conical transition section. This method can make the pump light coming from the multimode fiber import the inner clapping through the flank of double-clad fiber. Thereby the directional flank coupling pump is realized.

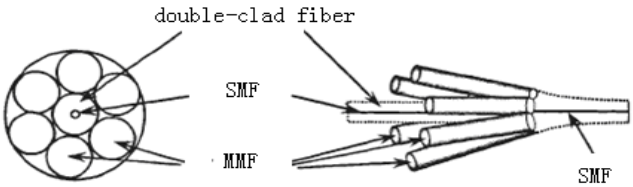

Fig. 3 Multimode optical fiber fused tapered directional coupler

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In this paper, the multimode optical fiber fused tapered flank coupling mode is used to realize the high efficient double-clad gain fiber.

Fig. 4 Composition diagram of large power, high speed semiconductor laser emission source

4. System testing

The seed source at 2.5Gbps high speed rate is generated using the EA external modulation technology. Two-stage fiber amplification technology is adopted to achieve the purpose of high gain and high power. The composition is as shown in Figure 5.

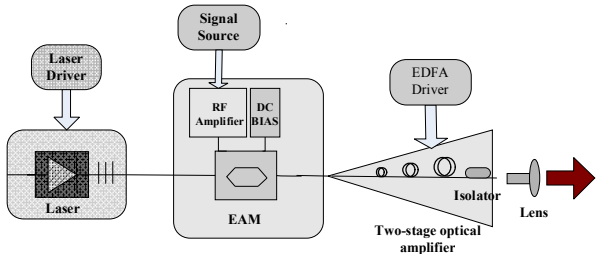

Fig. 5 The composition block diagram of large power, high speed semiconductor laser emission source

In the laboratory, the experimental testing system is composed of the high speed signal generator, broadband digital storage oscilloscope and the high sensitivity photoelectric detector. At a rate of 2.5Gbps rate, the received power of the detector is -30dBm. The eye diagram of received signal is as shown in Figure 6. The received bit error rate is as shown in Figure 7. The error code effect is very good.

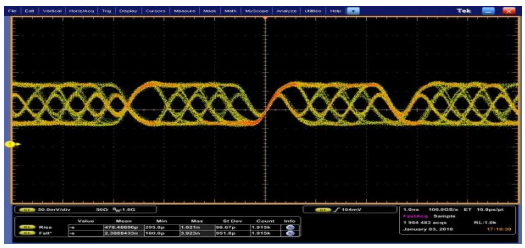

Fig. 6 The eye diagram of received signal at transmission rate of 2.5Gbps

5. Conclusion

This paper presents the key technologies of space laser communication transmission system. It is focused on solving the technology problem of high speed, high power. The mode, which combines the seed source of high speed with the high gain amplifier, is adopted to research on the EA modulation technology at high speed. The rate is up to 2.5Gbps. Two-stage fiber amplifying technology achieves high gain and high power laser output.

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