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The Research of PPM Modulation in Space Laser Communication Transmitting System

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Abstract: This paper uses the method of pulse MOPA fiber laser with the PPM modulation to achieve. This paper first describes the characteristics of space laser communication requirements and technical issues that need to be addressed, And then, according to the requirement analysis the MOPA transmitter program, and prove its accord the high power and the high rate what the space optical communication requirements. Through the analysis for PPM modulation mode, the MOPA type fiber laser based on the PPM modulation system is designed. Through the simulation verify its can reach 1 Mbps transmission rate and 5W average power. *Copyright © 2013 IFSA.*

Keywords: Laser communications, PPM, Fiber laser, Modulation, MOPA.

1. Introduction

In space Laser communication, we generally hope that the light source we use can meet the characteristics of high operating frequency, good output beam quality and narrow linewidth [1]. High-power laser light source is a key factor for space laser communication. The high-power fiber laser is a new light source, the fiber laser have a great advantage in beam quality, optical transmission characteristics, reliability and the size and also other areas in the same optical output power. High rate modulation technique makes very important impact on the performance of the laser communication system, it is one of the key technologies of optical communication [2]. Selecting the appropriate modulation and demodulation method depends on the channel characteristics of the system, so that the signal and the channel characteristic can match each other to make the way of the space laser link achieve communication more effectively and more reliably. Therefore, researchers on the modulation technique of fiber laser which can adapt to space optical communication transmission characteristics will be of great significance for the space laser communication's pre-research to application [3].

The fiber laser is characterized by large power to comply with the conditions of space optical communication, but it is difficult to achieve a high rate because of low repetition frequency [4]. PPM can achieve a high data transfer rate with a small light power in a given laser pulse repetition frequency, so it compensates for the disadvantage of the fiber laser. And the advantages of higher power utilization, high transmission efficiency and anti-interference ability are widely used in optical communication systems. So technology combined with a fiber laser and PPM modulation will become the hot in space optical communication.

2. Selection and Analysis of a Fiber Laser

For space laser communication tasks, the generation of power is very difficult and expensive, it requires the laser emission source with a higher transmit power and emission efficiency. Laser emission needs to consider peak-average power ratio, up to the peak power, the electro-optical conversion efficiency and total power consumption. Compromise considerations between various existing laser techniques to make a reasonable design choice [5], average power is sufficient, or the high-performance pulse lasers which are from the low power oscillator amplified to the required power level can satisfy space application requirements.

Due to the modulation option in this paper is the PPM modulation, first of all the type of fiber laser should be selected pulsed fiber lasers .In addition, the PPM modulation techniques must increase the laser pulse repetition frequency in order to obtain high code rate. After calculation, we require the laser peak power of 1000 W, repetition frequency of 200 kHz and the pulse width of 15 ns in order to achieve the transmission rate of 1 Mbps. For this, we propose the master oscillator power amplifier (MOPA) [6]. Seed source can guarantee that the output characteristics of the pulse of the laser beam for pulse fiber laser-based on MOPA technology. The optical fiber power amplifier can ensure that the output laser power and energy characteristics thereby obtaining excellent laser pulse characteristics and can greatly improve the output energy of the laser (power).

2.1. Selection of Seed Source

Seed source determines output laser pulse characteristics of pulse fiber laser [7]. This paper analyzes the characteristics of the fiber-optic laser modulation, then we must first start from the seed source of fiber lasers to analyze the output characteristics of the fiber laser, so the selection of seed source was particularly important in this paper.

Fiber acousto-optic Q-switched laser has output wavelength of 1070 nm nearby, just easy to zoom in doped Yb quartz fiber gain bandwidth [8]. And because of the direct fiber output we can achieve all-fiber structure by directly weld with the amplification system. However, due to the characteristics of the fiber itself, its cavity length is longer, so it is difficult to obtain a narrow pulse width output. At the same time due to the self- clamping effect, it is difficult to obtain a smooth pulse waveform output. Based on the above considerations, a small laser diode (LD) pumping shipped acousto-optic Q-switched *Nd:YAG* laser [9] (Fig. 1) as the source of the seed of the MOPA system.

As shown in Fig. 1, the laser source consists of the pump source, the coupled system, the laser crystal, the resonant cavity and the drive source. The laser source uses semiconductor pump technology, end-pump technology and acousto-optic Q-switched technology, it also specially designs laser crystal resonator and the driving source in order to obtain high efficiency, high power and high beam quality. where the pump source is selected semiconductor laser (LD) of 808 nm, so that the life of the laser source is up to 10,000 hours or more; Since the LD of 808 nm emission spectra fall exactly on the absorption peak vicinity of *Nd:YAG* crystal, the laser crystal selected *Nd:YAG*, by adjusting the working temperature of the LD it can make their emission wavelength be accurately adjusted to the absorption peak of the *Nd:YAG* crystal, thus greatly increasing the utilization of the pumping light; Seed source uses acousto-optic Q-switched intracavity modulation and take measures to compression chamber, so that the pulse width of signal light is maintained at less than 20 ns; Due to the high conversion efficiency of the laser source, the thermal effects of *Nd:YAG* crystal are reduced, combined with end-pump technology, and laser collimator technology makes laser source to achieve proximal film output, beam divergence angle compression to less than 1.5 mrad and the light emitting surface less than 2 mm.

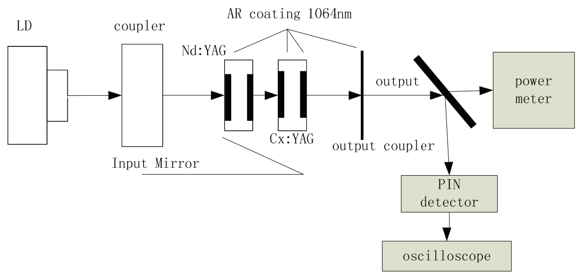

Fig. 1. Schematic diagram of experimental system of passively Q-switched laser.

In the operational state of the Q-switched, the stable Q-switched pulse output can be obtained when the modulation frequency is adjusted between 200 kHz - 600 kHz. As fixed modulation frequency is 1 kHz, the relations of the pulse width of output laser and the average power changing with the pump power and the repetition rate are shown as Fig. 2.

As can be seen from Fig. 2, pulse peak power gradually increases with the increase of the pump power, eventually stabilized. This is due to the gradual increase in the pumping rate, the level accumulated inversion particle of $Yb3+$ gradually increased until saturation, resulting in the above-mentioned changes of the pulse peak power. Changes in the pulse width is gradually reduced and stabilized.

2.2. Design of MOPA System

MOPA optical fiber laser is a laser emitting system on the basis of the seed source of a pulse adding one or several optical fiber laser amplifier systems, so the seed source can be obtained the laser output with higher energy of the single pulse, high average output power and high beam quality through several stages of amplification. Laser amplifier requires working material with sufficient population inversion to ensure the gain is sufficient to overcome the loss of the amplifier inside when the signal passes. According to the requirements of the system parameters, the fiber lasers based on MOPA architecture is shown in Fig. 3.

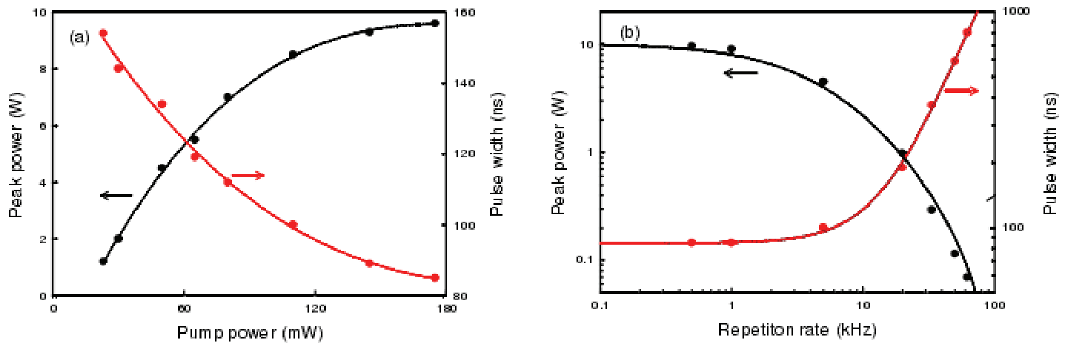

Fig. 2. Peak power and pulse width as a function of pump power and repetition rate.

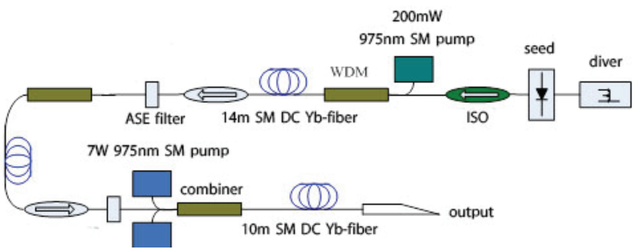

Fig. 3. Schematic of pulse fiber laser.

As shown in Fig. 3, the seed laser uses the way of acousto-optic Q-switched so that there is a large enough output power. So this paper uses two-stage amplification structure as in literature. The output signal light is coupled into the gain fiber by the optical coupler system after the optical isolator. The first level is the preamplifier system, the amplifier consists of a LD laser whose center wavelength is 975 nm as its pumping source, its output power is 30 W. Second level uses two LD lasers whose output power is 7 W, and the center wavelength is 975 nm as its pumping source. We obtained the second stage amplification of the pulse output using a Single mode doped double-clad chest fiber of length 16 m, and weld directly with the seed laser and gain fiber splicing through fiber coupler. Amplification stages used in the system adopt the structure of the backward-pumped, namely the signal light and the pumping light is coupled into the fiber respectively from both ends of the double clad fiber, this structure is conducive to obtain higher magnification and output power for the optical fiber amplifier.

The output power changing with the pump power of fiber laser primary amplification based on the MOPA architecture when it realizes the stable clamping is shown in Fig. 4:

The output power changing with the pump power of fiber laser secondary amplification based on the MOPA architecture when it realizes the stable clamping is shown in Fig. 5.

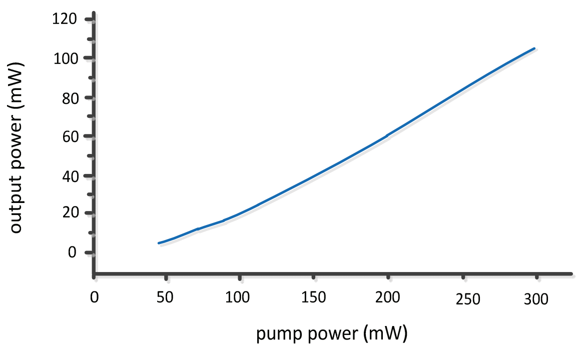

Fig. 4. The output power changing with the pump power in fiber laser primary amplification.

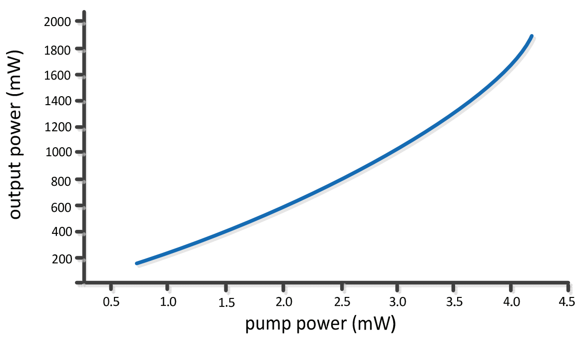

Fig. 5. The output power changing with the pump power in fiber laser secondary amplification.

The comparison can be seen by the previous figure, the pulse width of the output pulse is broaden and the smoothness of the curve is also declined after a primary and secondary amplification.

3. The PPM Modulation Analysis

Normally, we call the process of loading transfer information to the laser radiation as laser modulation, the device to complete the process is called a laser modulator, the laser is called carrier for playing the role of the "carry" information. Information passed is usually referred to as a modulated signal. Modulated laser is called a modulated wave or the modulated light. The modulation characteristic is defined as the relationship of the output signal of the laser with the changes in the modulated signal. This paper uses the pulse signal modulate laser. Laser output signal is observed by adjusting the various pulse repetition frequencies so that the laser works stably in the working point of the highest modulation efficiency.

3.1. Basic Principles of PPM

PPM [10] is a form of signal modulation in which *M* message bits are encoded by transmitting a single pulse in one of 2^M possible time-shifts. This is repeated every *T* seconds, so the information bits have been transmitted by an L-PPM modulation signal is $\log_2 M$. If the *n*-bits data could be written as $M=(m_1, m_2, ...m_n)$, then the mapping coded relation of the PPM modulation could be written as: $\phi : l = m_1 + 2m_2 + 2^{n-1}$, $m_n \in \{0, 1 \cdots n-1\}$, For a 4-PPM modulation, if M=(0,0), then L=0; if M =(1,0), then L=1; if M =(0,1), then L=2; if M =(1,1), then L=3; Then the slot positions of 0, 1, 2, 3 correspond as shown in Fig. 6.

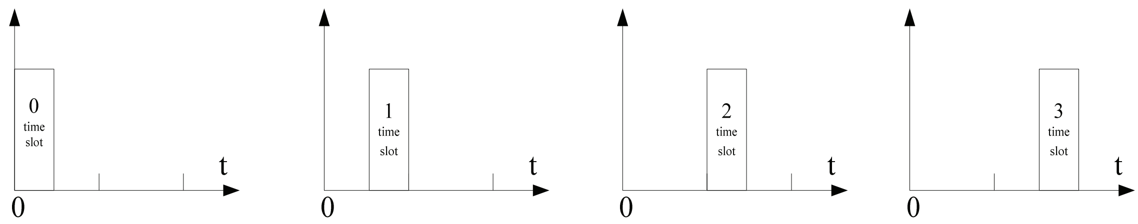

Fig. 6. L-PPM pulse position modulation diagram.

If a symbol rate of the digital baseband signal is $R_b=1/T_b$, the ideal low communication channel bandwidth it requires is $B=R_b/2$. The symbol rate of OOK signal and L-PPM signal respectively is $R_b=1/T_b$ and $R'_b=1/T'_b$. If messenger rate is same, $T'_b.L=T_b \log_2 L$, $B/B'=\log_2 L/L$ ($L=2^n$, *n* is integer.) L-PPM modulation has high requirements for the bandwidth.

Units pass the letter rate is an important parameter, namely the transmission bits number of per second per hertz γ.

$$\gamma = R/B\left(bit \cdot s^{-1} \cdot Hz^{-1}\right) \tag{1}$$

where *R* is the transmission rate, *B* is the signal bandwidth, and the units respectively are $bit \cdot s^{-1}$ and *Hz*. If the optical communication systems use a pulsed laser, the pulse duration is τ, the signal bandwidth is approximated as:

$$B(Hz) = \frac{1}{\tau}(s) \tag{2}$$

If the duty cycle of the OOK modulation symbols is τ_p, its unit messenger rate is:

$$\gamma_{OOK} = \left(1/T\right)/\left(1/\tau\right) = \tau_p \tag{3}$$

Signaling the number of slots in a single pulse position modulation is $L=2^n$,

Duty cycle is the same with OOK modulation, the width of the 2^n slots is $T_{PPM} = 2^n \cdot \tau/\tau_p$ .So units passing letter rate is:

$$\gamma_{PPM} = n \cdot \tau_p / 2^n \tag{4}$$

From the above analysis, in the same passing letter rate, the bandwidth occupied by the L-PPM modulation is increased and the required transmission rate is also increased compared with OOK modulation [11].

3.2. PPM Modulation Error Analysis

People can know that we usually describe the anti-interference ability of channel coding by using Hamming distance from error-correction coding theory. But when the signal has been modulated, BER of the systems depends on the Euclidean distance of signal sequence, the role of coding is to increase the Euclidean distance in signal sequence, thus to improve bit-error performance of the systems. If choosing the PPM modulation for the optical communication systems, no matter what the magnitude of the Hamming distance between the coded sequences is, in a PPM symbol, the Euclidean distance is a constant, and they cannot correspondent to each other, the equivalence between Euclidean distance and Hamming distance makes the impairment of the coding gain.

The essential of a PPM is a kind of partition modulation, the receiver needs to judge the positions of the high level in 2^M slots, so there may be the following as: When the PPM symbol errors occur, the error numbers of corresponding to the coding information will appear in different situations, it may err in an unitary bit, or continuous with *M*-bits errors, which causes partial "error diffusion" in the *M*-bits messages. This is one of the reasons why the coding gain would be impaired.

3.3. The Options Program of PPM with Fiber Laser

The paper uses high-speed FPGA design the PPM modulation system to driven fiber Q-switched laser, the fiber laser power is amplified using MOPA structure and PPM modulated signal is loaded on top of the fiber laser by external modulation to achieve PPM modulation technology of high-speed and high-bit-rate. The program structure is shown in Fig. 7.

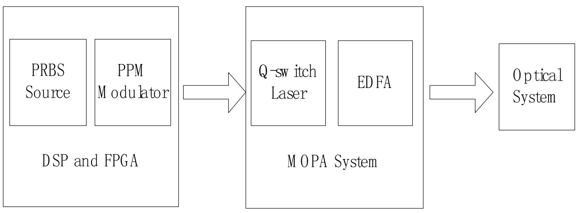

Fig. 7. Overall program of modulation system.

The modulation system is composed of three parts, including FPGA modulation driver, MOPA and an optical system. FPGA generates the PRBS sequence signal and the PRBS is mapped into the PPM code sequence. The PPM code sequence is used to drive the Q-switched lasers. Q-switched laser has drawbacks of low repetition frequency and small output power, so we choose the PPM modulation technology and an optical amplifier of MOPA architecture to solve the above drawbacks.

Through modulating a transmitting signal in the laser communication system, an easier transmitting signal form is converted to improve signal noise immunity and transmission efficiency, thereby increasing the SNR and eventually achieving the increase in the communication distance. To achieve this modulation system, the key lies in how the system convert binary signal into a PPM pulse signal [12]. Fig. 8 is a block diagram of the modulation system.

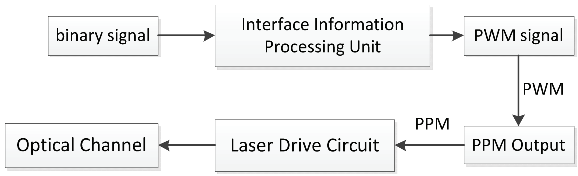

Fig. 8. The block diagram of PPM modulation system.

If binary information received directly is converted into the PPM pulse, first of all we must make a serial-to-parallel conversion for binary data, then a series designed of counter and comparator is made to achieve the PPM signal. Circuit logic is very complex. Firstly we do a transformation for binary information, the binary information first coded as PWM [13] (Pulse Width Modulation). Then using the correspondence relationship between the waveform of PPM and PWM, the PWM wave is converted into PPM wave through hardware trigger circuit, so that the PPM modulation can be relatively easy to achieve. The diagram of PWM to PPM wave transition is shown in Fig. 9.

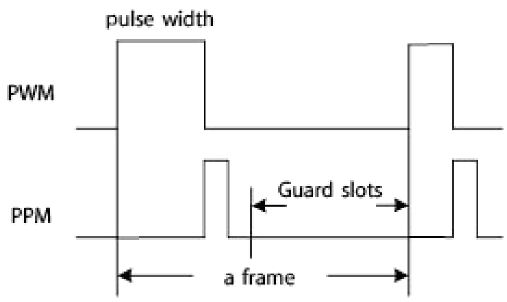

Fig. 9. Diagram of PWM to PPM wave transition.

The pulse width modulated signal (PWM) is a series of pulse whose width is changing. There is only one pulse at each frame period. The frame period is fixed. In time period composed by a series of time slots, i.e. in a fixed frame period consists only one slot position on the signal and only one of each frame period. L-PPM signal transmits data by pulses at different position. Both have in common is that the pulses are in the cycle of fixed length, i.e. within one frame period has one and only one pulse. The different points between the two are that the PPM transmits different data by the position of the pulse signal in a frame period, and the PWM wave transmits different data by pulse width changing. So that the system designs of the PPM modulation is converted to the design of the PWM modulation.

Two key problems exists when using FPGA generates the PWM wave, they are the cycle and pulse width of the PWM wave. The data sent by the host computer and hexadecimal numbers PPM modulated will affect the cycle and pulse width of the PWM wave .Disposed PPM modulation hexadecimal number is L, and the n-bit data to be transmitted is

M=(m_1, m_2, ...m_n). A PPM frame period is divided into information segment and protective segment, the information segment consists of L time slots, a slot width is denoted by τ, the guard period is denoted by T_D, the frame cycle of the system can be obtained as follows:

$$T_{PPM} = L * \tau + T_D \quad (5)$$

The frame rate of the system is:

$$f_R = \left(L * \tau + T_D \right)^{-1} \quad (6)$$

The messaging rate of the system is:

$$R = \left(\log_2 L \right) \Big/ \left(L * \tau + T_D \right) \quad (7)$$

The slot position corresponding to each group of sending data is denoted by L, the data and the position L mapping coding relationship is:

$$L = m_1 + 2 \cdot m_2 + ... + 2^{n-1} \cdot m_n \quad (8)$$

The frame cycle of the PWM and PPM are the same, as shown in Fig. 9 that is T_{PWM}=T_{PPM}, T_{PPM} can be obtained by formula (9).

$$T_{PPM} = T_{PWM} = 2 \cdot TPER \cdot T_{OSC} \quad (9)$$

TPER is the value of the timer period register. T_{OSC} is crystal cycle, PWM pulse width can be obtained by formula (10):

$$T_{ON} = 2 \cdot \left(TPER - CMPR \right) \quad (10)$$

CMPR is the value of register which needs to be calculated by the encoded data, and then be set by the software. Once T_{PPM} is known, *TPER* can be launched by the formula 9 then it can also be set by software. T_{ON} can be launched by the formula 10 with CMPR and TPER. Cycle and pulse width of the PWM wave are resolved, then PWM wave can be produced by designation.

3.4. PPM System Model

This paper designs 32-ary PPM modulation system, i.e. L=32. There is one pulse at 32 signaling time slots, where the laser repetition frequency is 200 kHz, one frame period is set as 10, then the protection time slot is T_D=5 µs, the clock frequency is set as 80 MHz, T_{OSC} =12.5 ns. As shown in Fig. 10, one frame period is divided into two parts, they are respectively 32 protection time slots and 32 communication slots, each time slot is T_s=5 µs /32=15.6 ns. So the design parameters of PPM modulation system are [14]:

1) Time slot frequency is f_s=64 MHz, frame frequency is 100 kHz;
2) Frame period is $T_f = \left(32 + 32 \right) \times T_S = 10 \mu s$;
3) A light pulses sends 5 bit data information in a cycle, the data are encoded in correspondence with a certain position of 32 communication slots one-to-one;
4) From the above analysis, a frame transmits 5 bits data, PPM modulation rate of the system can be drawn according to the formula (7):
$R = \log_2 L \Big/ T_f = 5bit \Big/ 5.096 \mu s = 1\, Mbit \Big/ s$

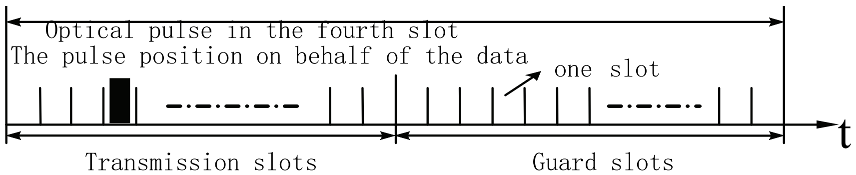

Fig. 10. The frame structure of the 32 - PPM modulation.

PPM modulation scheme was first proposed by the JRP tierce applied to space communications. Using this modulation requires a minimum average optical power in a given laser repetition frequency, and the maximum data transfer rate. In theory, the data transfer rate can reach thousands of bits per second. PPM modulation uses the intermittent cyclical light pulses as information carrier, the binary information of source control pulse position. The principle of PPM is that divided a period of time into M equal portions, each part is called a time slot, at one time slot sends a pulse within a frame time. The frame time is a PPM signal, it contains L time slots and a guard time.

With the development of high-speed digital signal processor (DSP) and field programmable gate array (FPGA) [15], it is easy to build modem system based on the DSP processor and FPGA at this stage as to achieve the PPM modulation with high performance of transmitting and receiving by software programming. In the digital transmitter and receiver of the PPM modulation, the received signal is sampled using a fixed clock frequency, then the sampled signal is processed using a DSP and FPGA to achieve signals decision decoding and signal synchronization. It is easier to achieve the PPM optical transmitter and receiver than using pure hardware.

This paper proposes the PPM all-digital modem system solutions according to the characteristics of the PPM modulation system with high-speed processing power of the DSP and flexible FPGA [16]. As shown in Fig. 11, the PPM modulation and demodulation system is divided into three parts, they are DSP control unit, FPGA processing unit and peripheral circuits and optical system. DSP realizes the function of modulation, it encodes the received binary data for PWM to achieve the control of the system, the communication with the host, the signal processing and analog-to-digital conversion; FPGA mainly realizes the function of the demodulation to extract slot synchronization signal and frame synchronizing signal and to decode the PPM signal. The circuit comprises the PWM trigger producing PPM narrow pulse circuit, the laser driver circuit, an optical system and the transmission channel, APD photo detector circuit.

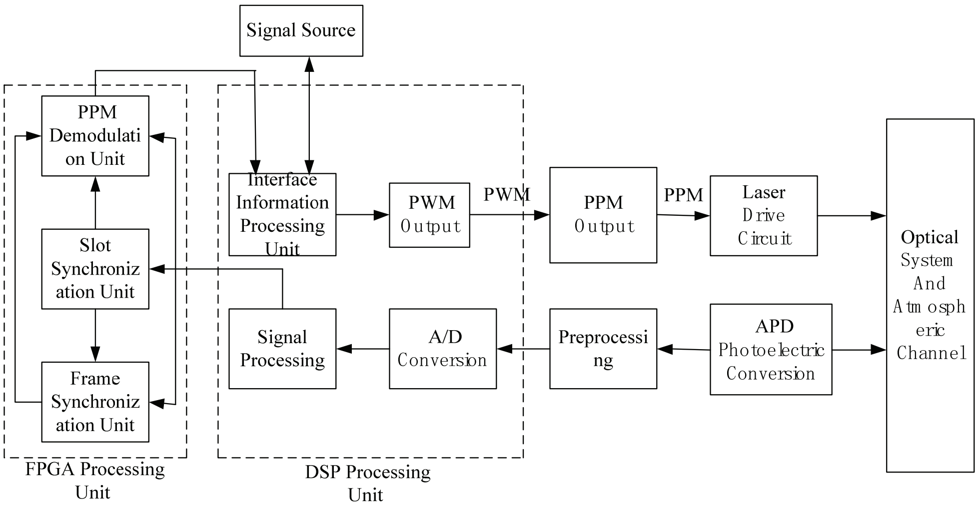

Fig. 11. PPM modulation and demodulation system model.

The focus of this thesis is to achieve the PPM modulation system using DSP and FPGA through detailed analysis of the principle of PPM modulation. According to PPM modulation system in this paper, the transmitted signal is modulated into PPM signals, PPM signal is transmitted into current or voltage by the laser driving circuit, the information is loaded into the light pulses which laser emits by controlling the laser directly. The present PPM modulation system is an internal modulation system, its essence is to convert the received binary signal into a PPM pulse to achieve the modulation of the laser, PPM modulation system principles will be introduced in the back [17].

4. PPM Modulation Simulation

4.1. PPM Modulation Experiments

The experimental equipment includes: a computer, a DSP system board, 5 V DC switching power supply, a DSP emulator and an oscilloscope. Oscilloscope selects Tektronix DPO7104, it has a 1GHz with three bandwidth model, it achieves real-time sampling rate of 10 GS/s in 4 channels to be able to observe transient phenomena. PWM waveform and PPM waveform can be observed in oscilloscope.

Computer transmits binary data to the DSP system board through the serial port. DSP system board convert binary data into the PWM pulse, then the PPM pulses is achieved by the trigger shaping, the three waveforms are displayed by oscilloscope. At last we verify the feasibility of the system and if it can achieve the correct modulation through comparative analysis.

As shown in Fig. 12, computer transmits binary data through the serial port. The waveform of the input random binary information can be displayed by the oscilloscope.

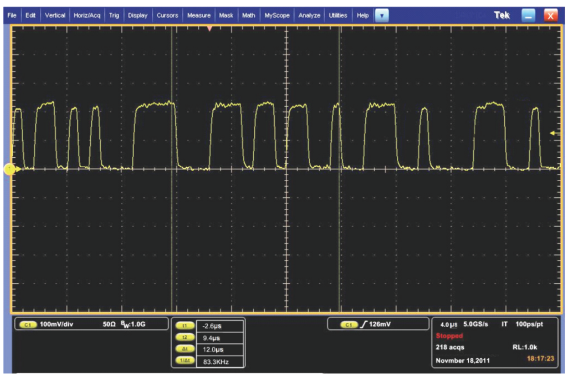

Fig. 12. Input data waveform chart.

PPM modulation is pulse modulation to a corresponding time slot position of some frame on the process which is actually a process of counting the output pulse. PPM modulation software modules achieved by the PWM modulation. PWM modulation module receiver the information and modulate it to the PWM wave to transmission. After a preliminary design the completion of algorithm, simulation of the system software. PWM modulation of the binary data output waveform through DSP processing board is displayed on the oscilloscope, as shown in Fig. 13, the oscilloscope interface is divided into 10-frame cycles, a fixed time period composed by a series of time slots is 4 µs. Pulse is in the cycles of this fixed length. There is only one pulse in each cycle, there is a total of 10 PWM output pulse waveform, and the pulse width is different. PWM wave transmits data by different pulse width, the pulse width corresponds with the binary information one-to-one, and so the PWM modulation in this verification is successful.

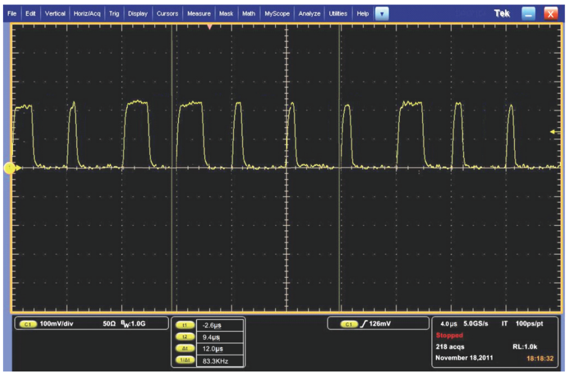

Fig. 13. PWM output waveform chart.

PPM is generated when PWM pulse through trigger shaping circuit at the falling edge of the PWM wave. The oscilloscope interface is divided into five-frame cycles in order to clear display PPM pulse on the oscilloscope and a frame is 4 µs, as shown in Fig. 14. This paper designs the 32-PPM modulation, one frame period is divided into signaling time slots and protection time slots, where the signaling time slots and protection time slots are both 32, one frame period is divided into 64 time slots, the first 32 slots is signaling time slot, the latter 32 slots is the protection time's lot. It can be observed by an oscilloscope, there is only one slot position having the signal in a fixed frame period, and the pulse position is different, the pulse position corresponds with transmitted information, PPM modulation transmits data through pulse in different positions, Fig. 14 shows that the modulation of the binary information is correct.

Binary data is converted into the PPM pulse signal after the PPM modulation, and the pulse position is determined by the transmitted data. Because of 32-PPM modulation system, 5 bit data is transmitted once a time, frame period is 4 µs .Thus modulation rate of 1Mbit/s can be achieved, modulation rate can meet the needs of the space optical communication. The PPM pulse level is TTL level, it becomes PECL level after level conversion which matches with driver chip ADN2841. So single-mode semiconductor laser can be driven, the information is loaded into the pulse of light to be emitted. The average power can reach 5 W after amplification, so that the modulation of the optical communication can be realized.

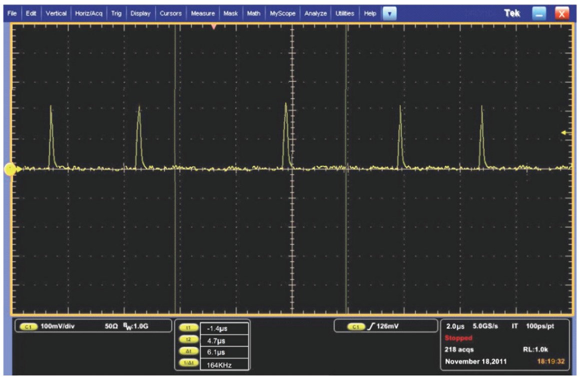

Fig. 14. The PPM modulation output waveform.

4.2. Analysis of Fiber Lasers with PPM Simulation

Simulation of the overall system design is shown in Fig. 15. Since there is not optical fiber laser whose repetition frequency is 200 kHz in this software, so the light source is a combination of the bit sequence generator and the optical pulse generator. The wavelength of the seed light source is 1064 nm, the input current is 25 mA, the peak current is set as 1.5 A, and the peak power is 800 mW, and then from the relationship between the average power and peak power: $P=P_w\tau/T$. The pulse width is 30 ns, T = 4 µs, then P is 6 mW. The light pulse emission wavelength is set as 1064 nm, and the transmit pulse power is 6 mW.

The signal and pump source are coupled into the Yb-doped optical fiber amplifier, the wavelength of pump light is 975 nm, the pump power is 200 mW, the fiber length is 14 m. After the primary amplification, the output power reaches 28 mW, as shown in Fig. 16.

The second stage amplifier uses two-way pump ways, the length of Ytterbium fiber is 10 m, the wavelength of forward pump light is 975 nm, pump power is 200 mW, the wavelength of backward pump light is 915 nm, pump power is 6 W, output power reaches 5.271 W after two zoom, as shown in Fig. 17.

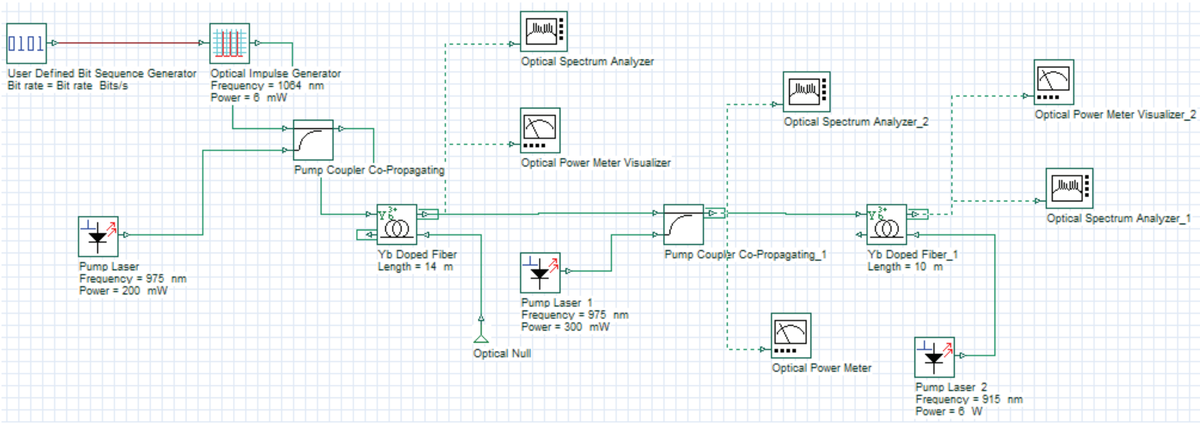

Fig. 15. The overall design of the simulation system.

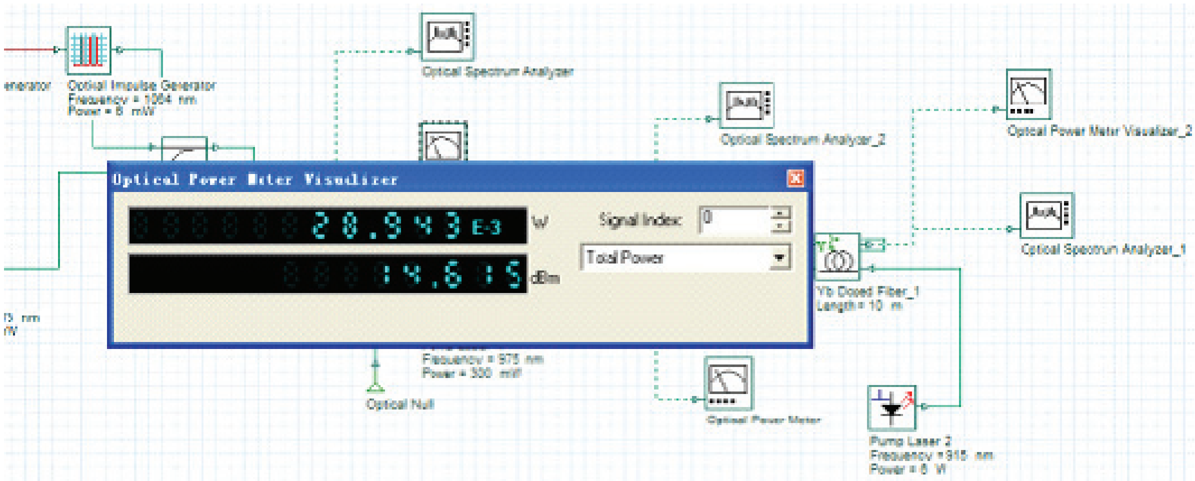

Fig. 16. The output power after the primary amplification.

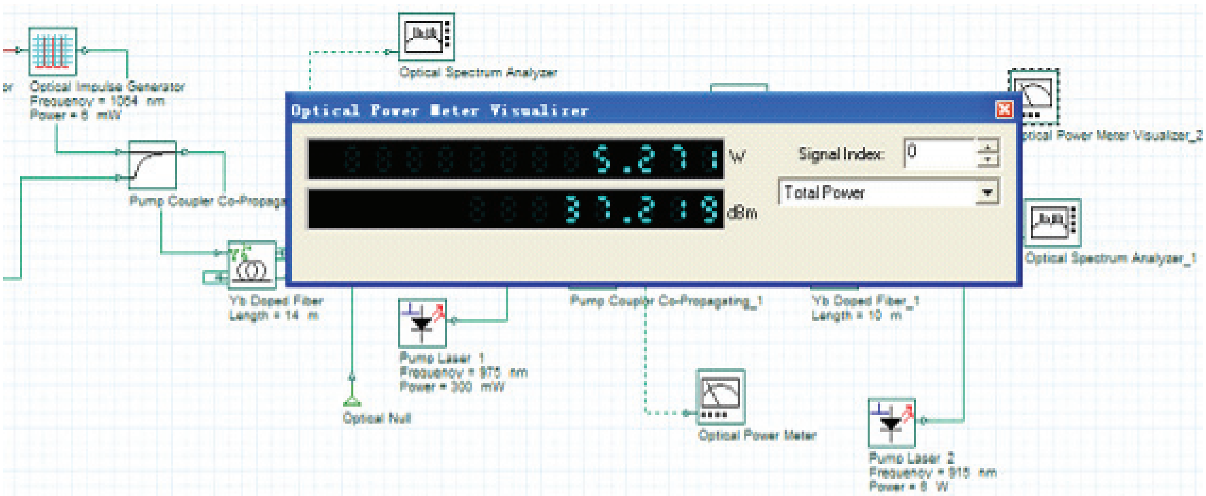

Fig. 17. The output power after the secondary amplification.

5. Conclusions

From this analysis process and experiment, we endeavor to seek some superiority of fiber laser with PPM modulation. And in the course of this exploration, we are able to see some ways in space laser communication.

This paper first describes the characteristics of space laser communication requirements and technical issues that need to be addressed. And then, according to the requirement analysis the MOPA transmitter program, and prove its accord the high power and the high rate what the space optical communication requirements. Through the analysis for PPM modulation mode, the MOPA type fiber laser based on the PPM modulation system is designed. Through the simulation verify its can reach 1 Mbps transmission rate and 5 W average power.

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References

[1] Hongxia Wang and Bangxu Yin, Watermarking-Based blind QoS assessment for wireless image communication, *Journal of Communications,* Vol. 8, No. 3, 2013, pp. 206-214.

[2] Yilma T. Desta and Jiang Tao, Multi band OFDM system model and Its performance evaluation for UWB communication, *Journal of Communications*, Vol. 8, No. 2, 2013, pp. 91-100.

[3] Fang Xu, Mohammad-Ali Khalighi, Salah Bourennane, Efficient channel coding for multipulse pulse position modulation in terrestrial FSO systems, in *Proceedings of the SPIE 7464, Free Space Laser Communications IX,* 74640M, 24 August 2009, pp. 1-12.

[4] G. G. Ortiz, J. V. Sandusky and A. Biswas, Design of an opts-electronic receiver for deep-space optical communications, *TMO Progress Report,* 15 August 2000, pp. 1-17.

[5] H. M. Pask, J. L. Archambault, D. C. Hanna, Operation of cladding-pumped Yb-doped cilica fibre laser in 1 dun region, *Elect. Lett*, Vo1. 30, No. 11, 1994, pp. 863-865.

[6] M. W. Wright, J. Kovalik, A fiber-based master oscillator power amplifier laser transmitter for optical communications, *IPN Progress Report 42-171*, 15 November 2007, pp. 1-18. http://ipnpr.jpl.nasa.gov/progress_report/42-171/171E.pdf

[7] J. Uchida, Y. Arimoto, Feasibility study on the tracking of geodesic satellites in laser communication demonstration experiment, in *Proceedings of the SPIE 4272, Free-Space Laser Communication Technologies XIII,* 28, June 20, 2001, pp. 28-37.

[8] Kong Lingfeng, Lou Qihong, Zhou Jun, Pulsed double-clad fiber laser, *Laser & Optoelectronics Progress*, Vol. 40, No. 5, 2003, pp. 28-32.

[9] H. Hemmati, M. W. Wright, A. Biswas, C. Esproles, High-efficiency pulsed laser transmitters for deep space communication, *SPIE,* Vo1. 3932, 2000, pp. 188-195.

[10] M. Cheng, M. Nakashima, J. Hamkins, B. Moision and M. Barsoum, A field-programmable gate array implementation of the serially concatenated pulse-position modulation decoder, *JPL Interplanetary Network Progress Report*, 2005, pp. 42-161.

[11] M. K. Simon and V. A. Vilnrotter, Multi-pulse pulse-position modulation signaling for optical communication with direct detection, *Jet Propulsion Laboratory*, Pasadena, California, 15 November 2003, pp. 1-22.

[12] M. Simon and V. Vilnrotter, Performance analysis and tradeoff for dual-pulse PPM on optical communications channels with direct detection, *IEEE Trans. Commun*., Vol. 52, No. 11, November 2004, pp. 1969–1979.

[13] M. W. Wright, D. Zhu, W. Farr, Characterization of a high-power fiber master oscillator power amplifier (MOPA) laser as an optical communications transmitter, *IPN Progress Report*, 15 May 2005, pp. 42-161.

[14] R. G. Lipes, Pulse-position-modulation coding as near-optimum utilization of photon counting channel with bandwidth and power constraints, *DSN Progress Report*, Vol. 42, 1980, pp. 108–113.

[15] R. M. Gagliardi, Error probability in lasercom PPM systems, in *Proceedings of the Nat Telecommon Conference*, New Orleans, LA, USA, 1981, pp. B10.1.1-B10.1.2.

[16] V. Vilnrotter, A. Biswas, W. Farr, D. Fort and E. Sigman, Design and analysis of a first-generation optical pulse-position modulation receiver, *IPN Progress Report,* 2002, pp. 42-148.

[17] Zhang Xin-Yi, Zhang Jian-Jun, Modeling analysis and optimization design of the thermostatical control system of laser instrument of semiconductor, *Microcomputer Information*, 24, 1-1, 2008, pp. 268-269.