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Research of Auto Control about Bias Voltage of High Speed EOM

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Abstract. It is presented that auto control about bias voltage of Electro-optical modulator (EOM) .It is different with the traditional manner that gives a constant voltage to the EOM. It takes an advantage that it makes EOM could have good effect in different temperature to acclimate all kinds of environment, because it always works at the half point of the zone of linearity. It uses photoelectric detector and error analysis to authenticate the drift of half-wave voltage of EOM.

1. Introduction

Recently, it Space laser communication is devoted more attention by more and more countries with the increasing of modern communication and information capacity unceasingly because of many advantages, such as small volume, strong anti-jamming capability, and good secrecy. The crystal shall be loaded a bias voltage determined by the half-wave voltage when the EOM is used. Its purpose is to guarantee the crystals can work in the linear area and the modulated signal has no distortion.

The traditional method of bias voltage is that the modulator is loaded a fixed bias voltage. The thermal cumulative effect of medium can make the half-wave voltage of electro-optic modulation crystal drift when the EOM is working at high-speed. If the crystal is loaded a fixed bias voltage, the EOM shall deviate from the midpoint of linear area. It makes the modulation signal distort. This has become the urgent to be resolved for the electro-optic communication system demanding increasing speed. This paper adopts the auto control technology for bias voltage of EOM. The feedback loop system is applied in loading the bias voltage. And the half-wave voltage drift of the EOM can be monitored at real-time. It makes the bias voltage change following the half-wave voltage and ensures that the static working point of EOM is the midpoint in the linear area. The high transmission rate is required. Therefore the laser modulation technology has become one of the key technologies for modern laser communications. While electro-optic modulation technology uses the outside modulation mode, the chirp phenomenon is reduced in the modulation. And the high-speed modulation is implemented easily. So it is used in the high-speed wireless optical communication system widely.

Half-wave voltage is an important parameter of electro-optic modulation technique. Half-wave voltage is determined by electro-optic modulation crystal characteristics itself, such as crystal material, crystal.

2. Half-wave voltage drift of EOM

Half-wave voltage is the important parameter describing the crystal's electro-optic effect. According to the half-wave voltage, the voltage which the transmission intensity controlled by electro-optic effect needs can be estimated.

In electro-optic modulation crystal of a horizontal effect, the mathematical model of half-wave voltage V_π is shown as followed.

$$V_\pi = \frac{\lambda}{2n_0^3 r_{22}} \frac{d}{l} \tag{1}$$

d: transverse size of crystal in the x axis; l: length of crystal; λ: wavelength of light source. n_0 refraction index in the direction of ordinary light in the transverse modulation crystal. r_{22}: electro-optic effect coefficient of electro-optic crystal.

For each parameter in the electro-optic effect, the refractive index of crystal is the parameter which is impacted maximally by the temperature. In the uneasily crystal, E1 and E2 are ordinary light and extraordinary light. The refractive index dispersion formula of ordinary light in the LiNbO3 as followed [2].

$$n_o^2 = 4.9310 + \frac{0.1173 + 1.64\times10^{-8}T^2}{\lambda^2 - (0.212 + 2.7\times10^{-8}T^2)^2} - 2.78\times10^{-2}\lambda^2 \quad (2)$$

In the formula (2), the refractive index depends on the temperature on the condition of certain wavelength of light source. And insert the formula (2) into formula (1), the relation can be obtained between half-wave voltage and temperature.

$$V_\pi = \frac{\lambda}{2r_{22}[4.9310 + \frac{0.1173 + 1.64\times10^{-8}T^2}{\lambda^2 - (0.212 + 2.7\times10^{-8}T^2)^2} - 2.78\times10^{-2}\lambda^2]^{\frac{3}{2}}}\frac{d}{l} \quad (3)$$

In this paper, $\lambda = 800nm$; $l = 3mm$; $d = 1mm$; $r_{22} = 3.4\times10^{-12} m/V$. The curve of half-wave voltage changing with temperature is shown as figure 1.

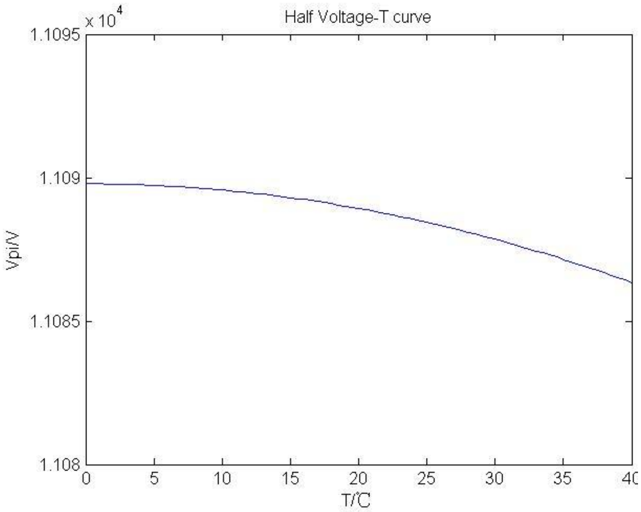

Figure 1. Curve of drift about half-wave voltage with temperature

In the figure 1, the half-wave voltage of high-power electro-optic modulation crystal changes with the temperature. When the half-wave voltage changes and the bias voltage loaded in the crystal is fixed, it will cause that the bias voltage will deviate from the midpoint of the linear area and the modulation distortion occurs.

In the transverse electro-optic modulation, the functional dependence between the output laser intensity and the incident laser intensity is:

$$I = I_0 siin^2\frac{\delta}{2} \quad (4)$$

δ: phase difference between the two polarized light components. When the crystal voltage V ($V = V_0 + V_m \sin\omega t$) is equal to the half-wave voltage V_π, the optical path difference generated by the two polarized light passing the crystal is equal to $\lambda/2$. And the phase difference δ is equal to π. The transmittance T is equal to 100%. So the formula (4) shall be changed into formula (5) as followed.

$$I = I_0 sin^2\frac{\pi}{2V_\pi}(V_0 + V_m\sin\omega t) \quad (5)$$

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V_0: DC bias. (It determines the work point of EOM). $V_m \sin\omega t$: modulation signal. In this formula, change V_0 or V_m, the output light intensity shall be changed correspondingly. If V_0 and V_m are fixed, the output laser intensity I will be changed when the half-wave voltage V_π drifts. So, in this paper, the detection scheme for the half-wave voltage is to monitor the input and the output of EOM using photoelectric detector. The change of light intensity reflects the half-wave voltage. And two beam splitters are placed in the input port and output port respectively. And the coupling ratio is 99: 1.

3. Setting bias voltage of electro-optic modulation crystal

The setting of static work point of EOM is very important when using for laser modulation. In the figure2, choosing the midpoint as work point, namely, $V = V_{\pi/2}$, the transmittance T is equal to 50% at this time. And the modulation curve can be looked on as a line approximately at this point. It is named the linear work region. The linear and undistorted signal can be modulated in this region. Choosing V =0 or $V = V_\pi$, the modulation signal will bring forth the multi-frequency distortion.

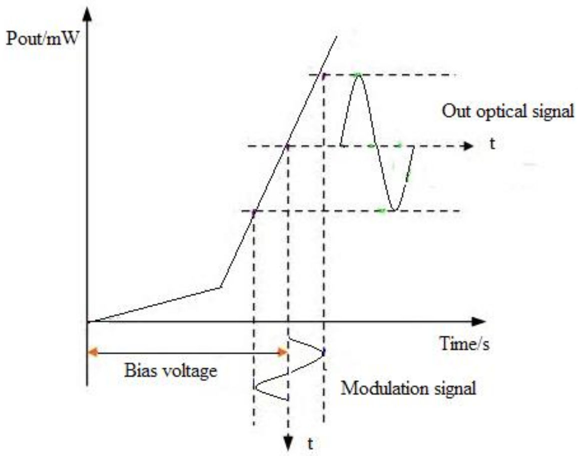

Figure 2. Curve of modulation characteristic about EOM

The two classical setting modes are as followed for bias voltage.

(1) Loading a fixed DC bias voltage on the elector-optic modulator, its value is half the half-wave voltage, namely, $V_\pi / 2$.

(2) Inserting a $\lambda / 4$ wave plate into modulator. It is called optical bias and its effect is as same as loading DC bias voltage $V_\pi / 2$.

The common feature of two modes is to load a fixed bias voltage to EOM. Using the EOM in high-speed system, the thermal accumulation generated by high-speed modulation signal in the crystal makes the crystal temperature rise. And the half-wave voltage of crystal is changed. At this time, the fixed bias voltage will deviate from the midpoint of characteristic curve and cause the modulation distortion.

The auto control technology brought forward in this paper is the improvement for the first traditional loading mode. On the basis of the first traditional loading mode, the close-loop feedback system is adopted to monitor the half-wave voltage of crystal at real-time. Using the auto control system, the bias voltage is adjusted according to the change of half-wave voltage. And guarantee the bias voltage is at the midpoint of linear area. The whole structure diagram of control system is shown as figure 3.

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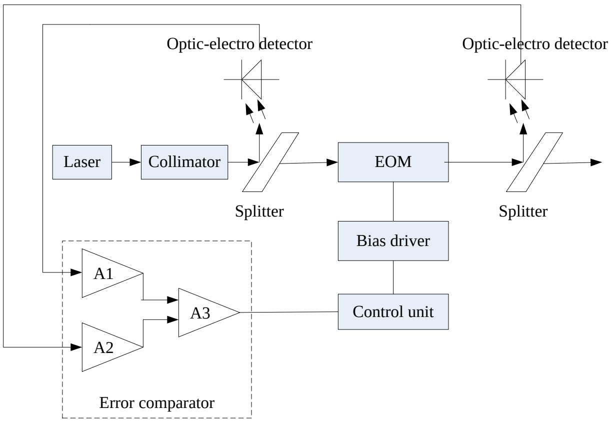

Figure 3. Auto control circuit of bias voltage

The work principle of control system is shown in above diagram. Using electro-optic detection method in this paper and placing a beam splitter in front of EOM and behind it respectively. Sample the same percent for the laser and the modulated laser, and convert the laser signal into the voltage signal through the photoelectric conversion circuit. When the modulator is working at the midpoint of linear modulation area, the modulation characteristic curve shows that the transmittance is 50%, namely, the modulated laser power is half of the unmodulated power. The two unequal voltages are got after photoelectric conversion and become equal to each other through the two amplifiers with different gain (A1 and A2). Then input them into differential amplifier, $u_1 = u_2$. It proves that the output of differential amplifier is zero.

When the working point of EOM drifts because of the temperature, the transmittance of modulation light will change. At this time, u_1 is fixed and u_2 is changed. The error through comparison is inserted into the control unit. The control unit adopts PID control mode in this paper. The DC bias voltage is adjusted repeatedly until the error is zero. It is to make the working point of EOM return to the midpoint of linear area. Such auto bias control system which can detect and control the bias voltage constantly makes the working point of modulator always at the midpoint of linear area and ensure that the laser is linear and undistorted.

4. Simulation

This paper uses Optisystem, which is a simulation software for professional optical communication. This paper simulates high-speed electro-optic modulation system according to the studied design, the simulation result is shown in Figure4.

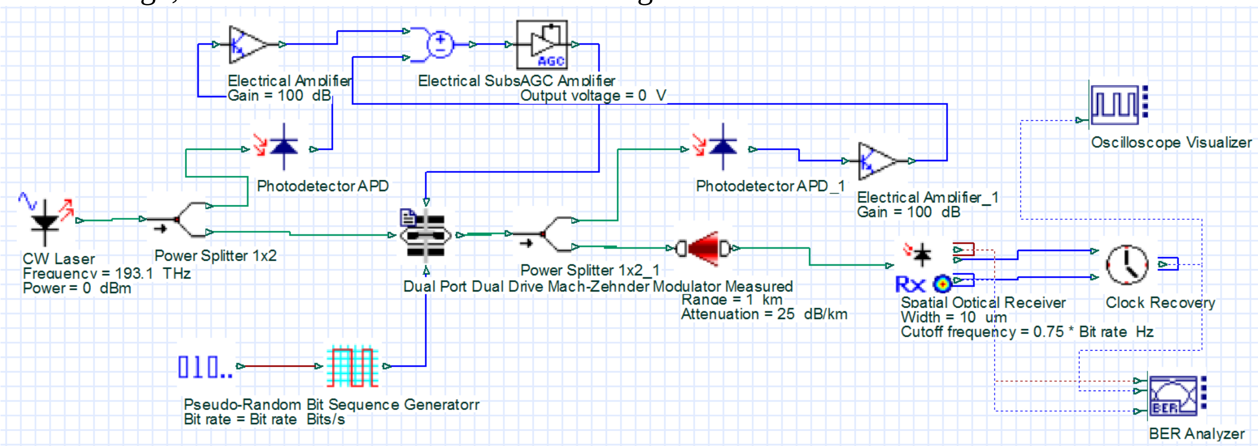

Figure 4. The electro-optic modulation simulation system

The simulation system uses laser free-space atmosphere channel to transmit message, the receiving end uses space receiving APD as the detector. It analyzes the received signal by the clock recovery module and an error analysis module .The electro-optical modulation system comprises a continuous semiconductor laser, a MZ EOM, a beam splitter, a photodetector, a power amplifier, a power comparator and a power automatic gain amplifier. The simulation system makes an analog for the modulation performance of the EOM when quiescent operating point drift occurs. When the modulation rate is 300Mbps and the modulator DC bias voltage is 45V, the drift is 2%. Figure 5 is the modulation output waveform when the modulation speed is 300Mbps for the electro-optic modulation system which adopting auto control system for bias voltage. The simulation results show the modulation effect is good, and the bias voltage automatic control unit plays a good regulation.

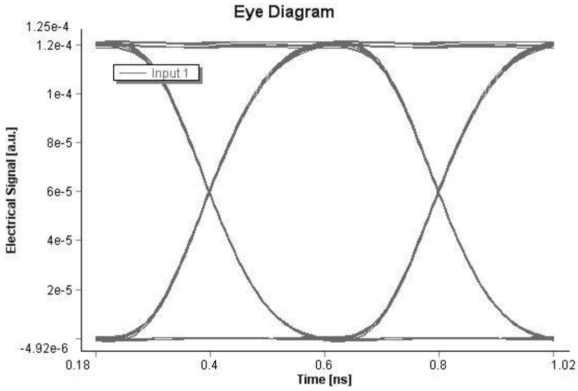

Figure 5. Output eye-diagram of EOM based on auto control of bias voltage

5. Summary

In this paper, the thesis aims to the auto control and stable technology of DC bias voltage for EOM in the high speed communication system. After analysis the shortcomings of traditional bias voltage, put forward the brand new auto control technology for bias voltage. It can enhance the modulation stability effectively. The drift of half-wave voltage for electro-optic modulation crystal can be identified using the photoelectric detection mode. But the optical energy will have some loss. In the future, the better measurement mode will be researched for half-wave voltage drift.

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