

Influence of connection forms of fiber Bragg grating on multi-channel dispersion compensation system

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Abstract: The multi-channel dispersion compensator by using chirped fiber Bragg gratings(CFBGs) has been one of the key technologies of high speed optical fiber communication system. The characteristics of reflection spectrum, time delay and dispersion of CFBGs with different connection forms are studied. By stress modulating and UV post-exposure, the uniform characteristics of the reflection spectrum of CFBGs are increased, and the influence of superposition effect caused by the parallel connection of CFBGs is decreased greatly. At the same time, the interference length is used to optimize the position of the cascaded CFBGs, and the cross talk can be decreased. By using the above optimized CFBGs connection forms,13 different wavelength CFBGs are cascaded in each dispersion compensator, and 20 CFBGs are parallel connected in each channel, a 13×10Gb/s 3100km ultra long G.652 fiber transmission system is successfully implemented without electric regenerator. The power penalty of the carrier-suppressed return-to-zero (CSRZ) code transmission system is only 2.5dB.

Key words: High speed optical fiber transmission system; Fiber Bragg grating; Dispersion compensation; Cascaded connection; Parallel connection

1 Introduction

Optical fiber communication network establishes the foot-stone of people's communication world because of its unparalleled huge capacity. Along with the solving of optical fiber loss, dispersion and nonlinear effect become the major obstacles for the development of high speed, big capacity optical fiber communication system. As the nonlinear effect can be conquered by dispersion, the key problem focuses on the dispersion problem, how to solve it economically and effectively is a research hotspot in the world.

The chirped fiber Bragg gratings (CFBGs) are compatible very well with most of present optical fiber communication systems. It has low transmission and insertion losses, and its refractive index modulation can be controlled in exposure process easily. The most attractive advantage of using CFBGs is that the dispersion and dispersion slope can be compensated and matched simultaneously^[1]. This is very important for wavelength division multiplexing (WDM) system. Now, the dispersion compensation of CFBGs is considered as a very good scheme.

In the long haul optical fiber transmission system, more and more CFBGs with different center wavelengths are need to be cascaded in one dispersion compensator, and more CFBGs with same center wavelengths are need in one channel. How to eliminate the interaction of cascaded CFBGs and how to optimize the characteristics of parallel connection CFBGs are serious problems that need to be considered. In this paper, the characteristics of CFBGs with different connection forms are studied. By stress modulating and UV post-exposure, the uniform characteristics of the reflection spectrum of CFBGs are increased, and the influence of superposition effect caused by the parallel connection of CFBGs is decreased greatly. At the same time, the interference length is used to optimize the position of the cascaded CFBGs, and the cross

talk can be decreased greatly. By using the above optimized CFBGs connection forms, a 13×10 Gb/s 3100km ultra long G.652 fiber transmission system is successfully implemented , the power penalty of the carrier-suppressed return-to-zero (CSRZ) code transmission system is only 2.5dB.

2 Characteristics of different connection forms of CFBGs

2.1 Parallel connection

In a WDM system, with the increase of transmission length, more and more CFBGs are need in one channel. Fig.1. gives the reflection spectrum with the number of CFBGs from one to six. Here, the original center wavelength and 3dB bandwidth from CFBG1 to CFBG6 are 1547.788nm, 0.498nm. 1547.777nm, 0.427nm. 1547.784nm, 0.507nm. 1547.777nm, 0.496nm. 1547.758nm, 0.467nm. 1547.767nm,0.449nm. And the six CFBGs are connected by using six circulators.

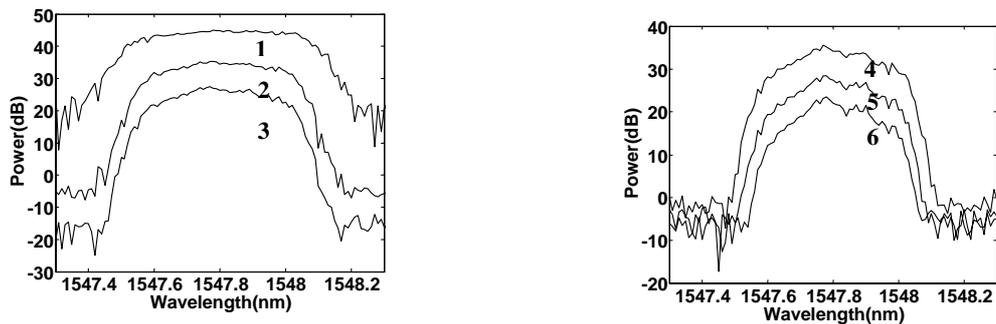


Fig.1 Reflection spectrum of different number of parallel connection CFBGs

From Fig.1 ,we can see that the more of the CFBGs ,the higher of the fluctuation of the reflection spectrum, and at the same time, the narrower of the 3dB bandwidth of the CFBGs. The fluctuation of the reflection spectrum is increased from 0.5dB to 1.7dB, and the 3dB bandwidth is decreased from 0.498nm to 0.119nm. The time delay ripple is also increased from 29.4ps to 44.6ps, as shown in Fig.2.

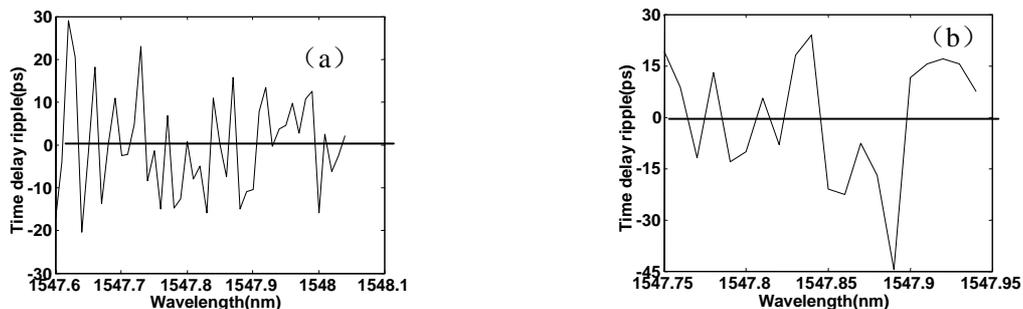


Fig.2 Time delay ripple with different number of parallel connection CFBGs

(a)one CFBG (b) six CFBGs

2.2 Cascaded connection

With the increase of channels number in WDM system, more and more CFBGs with different center wavelength are need to be cascaded in one channel. In our experiment, four CFBGs are cascaded, and the center wavelengths from CFBG1 to CFBG4 are 1547.411nm, 1548.984nm, 1550.437nm and 1552.016nm.

The reflection spectrum and time delay ripple of CFBG1 are measured when the numbers of the cascaded CFBGs are increased from 1 to 4. The results show that its 3dB bandwidth is relatively stable, the fluctuation of reflection spectrum is increased from 0.5dB to 1dB. The time

delay ripple is increased from 26.5ps to 132.1ps. As shown in Fig.3. We can see that the time delay ripple is increased greatly with the increase number of CFBGs.

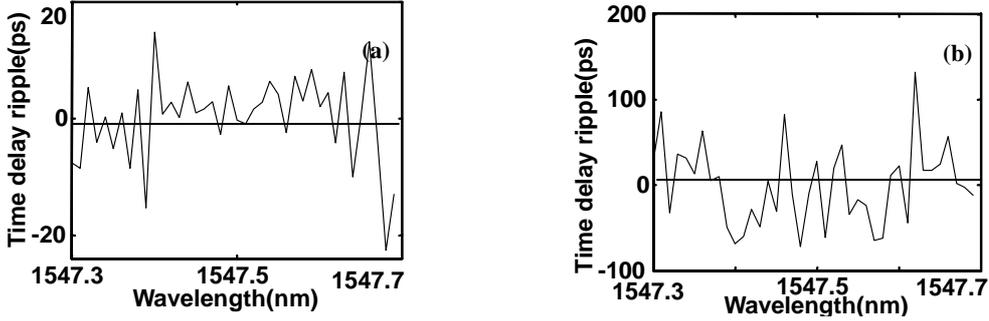


Fig.3 Time delay ripple of CFBG1 with different number of cascaded CFBGs
(a)one CFBG (b) four CFBGs

3 Optimization of the characteristics of CFBGs

3.1 Stress modulating and UV post-exposure

It is very important for the dispersion compensator to have CFBGs with same center wavelengths that required by the ITU-T criterion in one transmission channel. By years of research, we found that during the fabrication course of CFBGs, if different stress is on the photo-sensitive fiber, the CFBGs will have various center wavelengths, and the shift of the center wavelength have direct ratio to the stress^[2]. The modulation of the refractive index of the fiber core (MORIC) is,

$$\Delta n = \Delta n_0 + \Delta n_s (1 - e^{-kp}) \quad (1)$$

where, Δn_0 is the MORIC without stress. Δn_s and k are parameters that related to the stress.

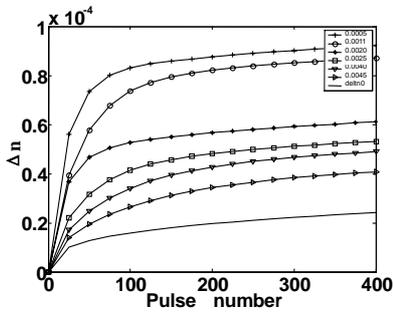


Fig.4 MORIC with different stress on the fiber

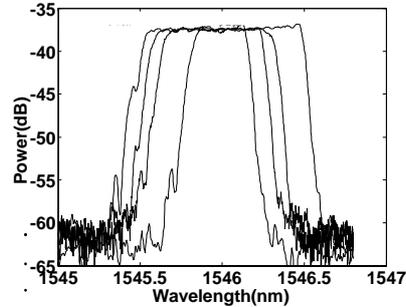


Fig.5 Reflection spectrum of CFBGs with different stress on the fiber

If the length of the fiber without stress is L , the length change with stress is ΔL , and then the strain can be simply defined as $\Delta L/L$. When the strain is increased from 0, 0.0005, 0.0011, 0.0020, 0.0025, 0.0040 to 0.0045, the MORIC will be changed, as shown in Fig.4. We can see that different stress on the fiber will make various MORIC, then the CFBGs will have different center wavelengths, as shown in Fig.5. The center wavelengths of the four CFBGs are 1545.514nm, 1545.581nm, 1545.934nm, 1546.158nm when different stress is on the fiber.

The center wavelength of CFBG can be adjusted exactly by UV post-exposure^[3-4], our experiment results show that the center wavelength of CFBG can be adjusted in a range of 0.3nm. Fig.6 is one of the experiment results. The line 1 and 2 are the reflection spectrum of a CFBG without and with UV post-exposure, the center wavelength of the CFBG is adjusted from

1547.733nm to 1547.929nm.

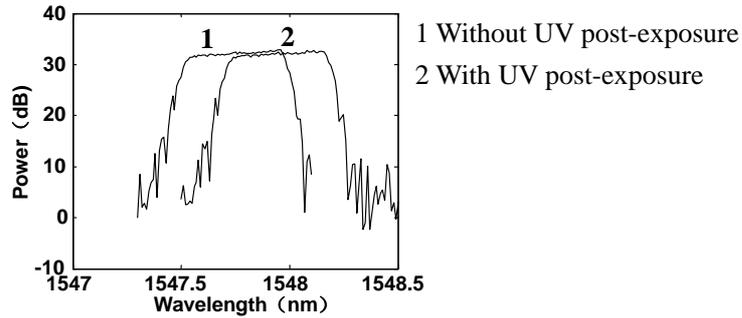


Fig.6 Reflection spectrum of CFBG without and with UV post-exposure

3.2 Position optimization of cascaded CFBGs

How to eliminate the interaction of cascaded CFBGs is a serious problem. By years of research, we have developed an asymmetry couple method that could solve the problem, the CFBGs should be connected with an incoherent fiber length between two CFBGs. By using the method, the four CFBGs that used in Fig.3 are connected again, and the total time delay ripple is decreased to 39.2ps. As shown in Fig.7.

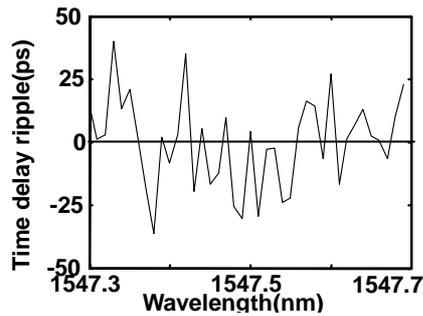


Fig.7 The time delay ripple of four cascaded CFBGs

4 The application of CFBGs dispersion compensator in a WDM system

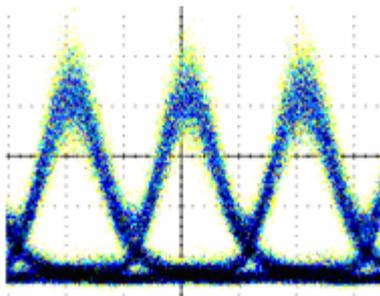


Fig.10 Eye diagrams after 3100km transmission without FEC

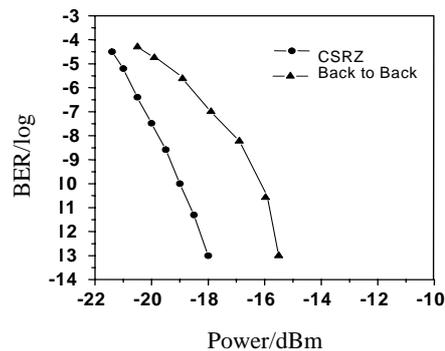


Fig.11 The BER of 3100km transmission

Based on above theory, a high precision scanning stage is built, the stress on the photo-sensitive fiber can be controlled accurately, so the CFBGs can be fabricated repeatedly and its center wavelength can be adjusted exactly by UV post-exposure for the dispersion compensation of one channel in the WDM system.

A 13×10 Gb/s 3100km ultra long G.652 fiber transmission system is built^[5], 13 CFBGs with different center wavelengths are connected with an incoherent fiber length between two CFBGs. And in each channel 20 dispersion compensators are used which are made by the home-made CFBGs that have the uniform center wavelengths and 3dB bandwidths.

Without Forward error correction(FEC), the eye diagram after 3100km G.652 fiber transmission with CSRZ code of one channel is shown in Fig.8. The center wavelength of the channel is 1555.748nm. The power penalty is only 2.5dB. As shown in Fig.9.

5 Conclusions

By optimizing the fabrication process of CFBGs, and decreasing the influence of connection forms of fiber Bragg grating on multi-channel dispersion compensation system, the CFBGs can be made repeatedly, and the interaction of cascaded CFBGs can be decreased greatly.

A 13×10Gb/s 3100km transmission system on G.652 fibers with dispersion compensated by CFBGs is implemented, the power penalty of CSRZ code transmission system is only 2.5dB. The achievement of the transmission system on G.652 fiber with dispersion compensated by CFBGs means that it is feasible for the dispersion compensation scheme by CFBGs. We can expect that the CFBGs will play a very important role in the future's optical fiber communication system.

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