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Analysis of Regularity on Raman Crosstalk Cancellation via the Wavelength Conversion

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Abstract Theoretically analyzes the Raman crosstalk cancellation under the wavelength conversion technologies which used in central transmission in the dense wavelength division multiplexing system. The regularity of output-power and amplifier is given, and the simulations has important significances in further study.

Key words nonlinear optics; Raman effection; wavelength conversion; crosstalk

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波长变换技术对拉曼串扰的影响

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摘要 从理论上分析了在密集波分复用通信系统的传输过程中利用波长变换技术后,各信道的输出规律,得到了消除拉曼串扰的放大倍数,并通过数值仿真进行了验证,对于进一步研究波长变换技术对拉曼串扰的影响有着重要的意义。

关键词 非线性光学;拉曼效应;波长变换;串扰

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1 Introduction

With the development of social economy, people hope to have more support in faster and more reliable communication, optical fiber communication technology has developed rapidly in this demand. Dense wavelength division multiplexing (DWDM) technique is one of the key to solve these demands[1-4]. But, the crosstalk between channels which caused by stimulated Raman scattering is becoming more and more serious with increasing number of channels. In order to eliminate this effect, the wavelength conversion technology is introduced into the process of communication. Wavelength conversion technology is used in the short wavelength channel and long wavelength channel signal symmetry transform in the optical fiber transmission, and then continue to transmit.

1997, Marhic pointed out that using the wavelength conversion technology can eliminate two of Raman crosstalk channel model[5]; 1999, from the ordinary discrete differential equations governing the evolution of stimulated Raman scattering power exchange between channels in wavelength division multiplexed systems, Grandpierre gave an exact analytical solution for the evolution of stimulated Raman crosstalk[6]; 2007, Hou proposed in the case of initial power input such as transient models could be eliminated by wavelength conversion technology of Raman crosstalk by numerical simulation[7].

This paper analyzes the Raman crosstalk cancellation under the wavelength conversion technologies which used in central transmission in the DWDM system.It has important significance in eliminating the nonlinear effects in optical fiber transmission, and improving the quality of

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communication.

2 Theory analysis

In the same linear loss, different channel spacings and different input powers, the solutions under the steady stimulated Raman scattering (SRS) coupled wave equation in one-way DWDM quartz optical fiber transmission system are as followed[8]

$$\begin{cases} p_i = p_i(0)\exp(-\alpha z)\dfrac{p_\Sigma(0)}{\sum\limits_{j=1}^{N}\dfrac{\bar{\nu}}{\nu_j}p_j(0)\cdot\exp(G_{ji})}, i=1,2,\cdots,N \\ p_i(0)=n_i(0)h\nu_i \\ p_\Sigma(0)=\sum\limits_{j=1}^{N}p_j(0)\dfrac{\bar{\nu}}{\nu_j} \\ G_{ji}=-\dfrac{k}{\bar{\lambda}MA_e}(\tilde{\nu}_j-\tilde{\nu}_i)\cdot p_\Sigma(0)\cdot L_e \end{cases}, \tag{1}$$

Where $p_\Sigma(0)$ is the initial total optical power of input, G_{ji} is Raman amplification coefficient corresponding to the channel, L_e is the effective distance, A_e is the effective cross-sectional area, M is coefficient of polarization- maintaining, $\bar{\lambda}$ is the average wavelength, $\tilde{\nu}_j$ is the wavelength of the j channel, k is a least-squares fit slope of the line.

After the optical signal transport to a certain distance (for example L_s), amplification and wavelength conversion are carried on, the output power of 1 channel is expanded as input power of N channel, and the output power of 2 channel is expanded as the input power of N−1 channel, and so on.

After conversion,the power of channel after conversion is

$p_i^{'}=Ap_{N-i+1}$ (A is magnification), $p_\Sigma^{'}(0)=A\sum\limits_{j=1}^{N}\dfrac{\bar{\nu}}{\nu_j}p_{N-j+1}(L_s)$, $L_e^{'}=\dfrac{1-\exp(-\alpha z)}{\alpha}$, $G_{ji}^{'}=-\dfrac{k}{\bar{\lambda}MA_e}(\tilde{\nu}_j-\tilde{\nu}_i)\cdot p_\Sigma^{'}(0)\cdot L_e$.

The output power after conversion is

$$p_i^{'}(z)=p_i^{'}(0)\frac{p_\Sigma^{'}(0)\exp(-\alpha z)}{\sum\limits_{j=1}^{N}\dfrac{\bar{\nu}}{\nu_j}p_j^{'}(0)\exp(G_{ji}^{'})}=\frac{p_\Sigma^{'}(0)\exp(-\alpha z)}{\sum\limits_{j=1}^{N}\dfrac{\bar{\nu}}{\nu_j}\dfrac{p_j^{'}(0)}{p_i^{'}(0)}\exp(G_{ji}^{'})}, \tag{2}$$

among them ,

$$\frac{p_j^{'}(0)}{p_i^{'}(0)}=\frac{Ap_{N-j+1}(L_s)}{Ap_{N-i+1}(L_s)}=\frac{p_{N-j+1}(0)}{p_{N-i+1}(0)}\exp[G_{(N-j+1)(N-i+1)}], \tag{3}$$

Will Equ.(2) to Equ.(3),get

$$p_i^{'}(z)=\frac{p_\Sigma^{'}(0)\exp(-\alpha z)}{\sum\limits_{j=1}^{N}\dfrac{\bar{\nu}}{\nu_j}\dfrac{p_{N-j+1}(0)}{p_{N-i+1}(0)}\exp[G_{(N-j+1)(N-i+1)}]\exp(G_{ji}^{'})}. \tag{4}$$

In the same linear loss, different channel spacings and different input powers in the DWDM system, the regularity of output-power is given by Equ.(4).

We can eliminate the Raman crosstalk between channels when $G_{ij}^{'}=-G_{(N-j+1)(N-i+1)}$.

Take into the relevant parameters, we can get

$$A=\frac{1-\exp(-\alpha L_s)}{1-\exp(-\alpha z)}\cdot\frac{\sum\limits_{j=1}^{N}p_j(0)\dfrac{\bar{\nu}}{\nu_j}}{\sum\limits_{j=1}^{N}p_{N-j+1}(L_s)\dfrac{\bar{\nu}}{\nu_j}}\cdot\frac{\tilde{\nu}_{N-i+1}-\tilde{\nu}_{N-j+1}}{\tilde{\nu}_j-\tilde{\nu}_i}. \tag{5}$$

If the channel spacing as same,

$$A=\frac{1-\exp(-\alpha L_s)}{1-\exp(-\alpha z)}\cdot\frac{\sum\limits_{j=1}^{N}p_j(0)\dfrac{\bar{\nu}}{\nu_j}}{\sum\limits_{j=1}^{N}p_{N-j+1}(L_s)\dfrac{\bar{\nu}}{\nu_j}}, \tag{6}$$

and then,

$$p_i^{'}(z)=\frac{p_{\Sigma}^{'}(0)\exp(-\alpha z)}{\sum_{j=1}^{N}\frac{\bar{\nu}}{\nu_j}\frac{p_{N-j+1}(0)}{p_{N-i+1}(0)}}. \tag{7}$$

Through the theoretical analysis we find that, if the L_s is given, we can eliminate the Raman crosstalk when magnification to meet Equ.(6), and the regularity of output-power is given by Equ.(7).

3 Simulation results and analysis

During the simulation, the number of channel is 20,the adjacent channel spacing is $\Delta_\lambda = 0.8\times10^{-9}$m , the first channel wavelength is $\lambda_1 = 1.53721\times10^{-6}$m, $A_e = 5.3\times10^{-11}$ m^2, M=2 , $k = 2.35\times10^{-16}$, $\alpha = 4.6\times10^{-5}$m^{-1} , L_s=50 km, after transform transmission distance of 50 km, the initial input power is shown in table1.

Table 1 Initial input of each channel optical power

Channel	Power /W
1	0.2
2	0.19
3	0.18
4	0.17
5	0.16
6	0.15
7	0.14
8	0.13
9	0.12
10	0.11
11	0.10
12	0.09
13	0.08
14	0.07
15	0.06
16	0.05
17	0.04
18	0.03
19	0.02
20	0.01

Figure 1 to Fig.3 are the simulation results.

Figure 1 shows the initial input of each channel optical power and the output before wavelength conversion at 50 km, from it we can see in the distance of 50 km, the output power of each channel no longer meets the geometric relationships for Raman scattering effect.

Figure 2 shows the output power of p1 per kilometer before 50 km and after 50 km,from it we can see that before 50 km, p1 transfers power to the other channel by Raman scattering effect, after 50 km, the output power of p1 first increases then decreases, because after wavelength conversion, the other channel transfers power to p1, with the transfer attenuation greater than the p1 transfers power to the other channel.

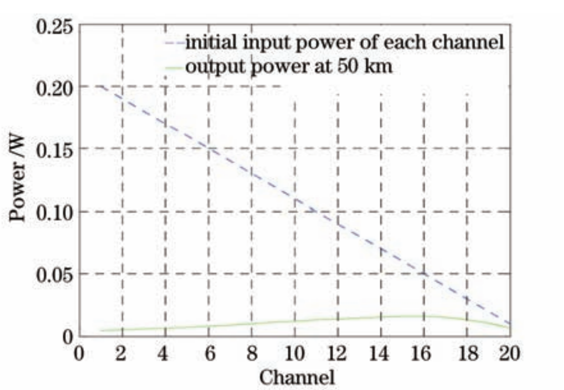

Fig.1 Initial input of each channel optical power and the output before wavelength conversion at 50 km

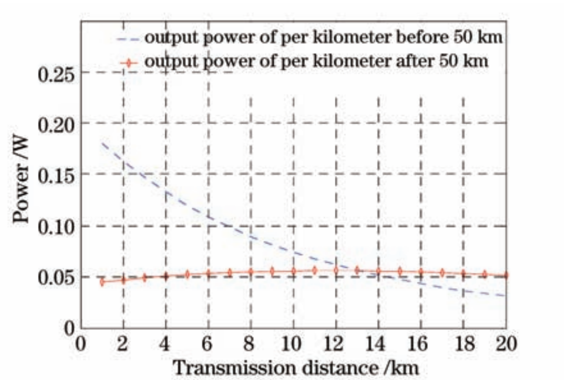

Fig.2 Output power of p1 per kilometer before 50 km and after 50 km

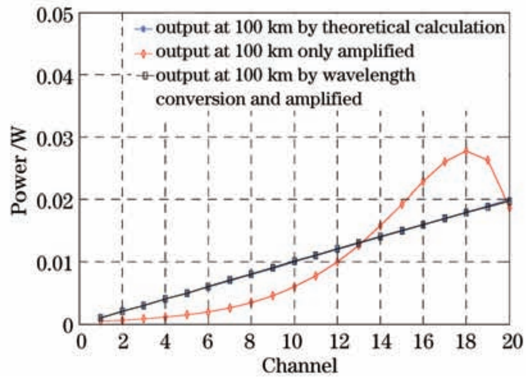

Fig.3 Output at 100 km only amplified, the output at 100 km by wavelength conversion and amplified and the output at 100 km by theoretical calculation

Figure 3 shows the output at 100 km only amplified, the output at 100 km by wavelength conversion and amplified and the output at 100 km by theoretical calculation, from it we can see the output at 100 km only amplified has not geometric properties. But, after transform amplification at 50 km, the output at 100 km has geometric properties , and theoretical calculation and numerical simulation results have good consistency, which verifies the correctness of the theoretical derivation.

4 Conclusion

The theoretical derivation from the steady state mode is carried on, not only gives the regularity of output- power in the same linear loss, the same channel spacing and different input powers in the DWDM system, but also gives the magnification which can eliminate the Raman crosstalk and gives the regularity of output-power after eliminating the Raman crosstalk effect.

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