行政院國家科學委員會專題研究計畫成果報告

摻鉺光纖放大器使用光纖光柵等化輸出功率以補償波長多工系統四波混合及拉曼串音所造成的能量不等

The study of fiber gratings on erbium doped fiber amplifier to reduce noise and compensate the unequalized power due to FWM and Raman crosstalk in WDM system

計畫編號：NSC88-2215-E-009-007

執行期限：87 年 8 月 1 日至 88 年 7 月 31 日

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一、中文摘要：

本計劃研究在波長多工通信系統中，使用寫上光纖光柵的摻鉺光纖補償四波混合效應及拉曼串音所造成的不同波道信號能量不均的現象。在傳輸光纖中，四波混合效應使信號能量減低且產生雜訊，拉曼串音造成高頻波道信號減弱而放大低頻波道的信號。我們將不同中心頻率的光纖光柵寫在摻鉺放大器的不同位置，藉由光柵反射濾波的特性，可補償信號能量不均的現象且過濾雜訊。

關鍵詞：拉曼串音，四波混合

Abstract:

We study the fiber gratings which mask on the erbium doped fiber amplifier to reduce noise and compensate the unequalized power due to the four-wave mixing and Raman crosstalk in the wavelength-division-multiplexing transmission system. The four-wave mixing reduces the power of signals and produces noise. The fiber medium provides gain to the longer-wavelength channels at the expense of the shorter-wavelength channels due to Raman crosstalk. We can mask grating with different center frequency on the different position. On Bragg reflection, the fiber grating can equalize the channel output and filter out the noise. For the requirement of increasing the signal to noise ratio and equalizing the channel output power of EDFA.

Keywords: Raman crosstalk 、Four-wave mixing.

二、緣由與目的

Wavelength division multiplexing (WDM) technique, combined with erbium-doped fiber amplifier (EDFA), has become very attractive for high speed and high capacity optical transmission systems. However, in the WDM system, the FWM and Raman crosstalk will reduce the multichannel transmission distance[1-3]. Satisfying the phase-matching requirement, the new frequencies ($f_1+f_1-f_2$ and $f_2+f_2-f_1$) are produced due to FWM. The amplified spontaneous emission noise increases seriously the efficiency of FWM and degrades the transmission system[4]. The effect of FWM depends on the signal power, the channel spacing, the dispersion of fiber, and the transmission distance. Although we can use the method of unequal channel spacing to reduce the efficiency of FWM, the noise induced by FWM can't be cancelled completely. In addition to the FWM, the collisions also induce Raman crosstalk among channels. Satisfying the self phase-matching of Raman scattering, the fiber medium provides gain to longer-wavelength channels at the expense of the shorter-wavelength channel[5]. The energy of shorter-wavelength channel decreases among the transmission distance while that of longer-wavelength channel increases. In order to overcome this difficulty, we have proposed the flattened fiber amplifier by using fiber Bragg gratings [6]. The new technique employs the FBG to flatten the signal gain of a WDM system. The FBGs with different center frequency can be written at different positions of EDFA to reflect the signal of different channels. By designing the written position of each FBG in the EDFA, the signals of different channels can obtain the equal gain in the backward direction, and the signal to noise ratio and the energy conversion efficiency will not be decreased.

三、結果與討論

The EDFA can be modeled as a homogeneously broadened two-level system. The pump wavelength $\lambda_P = 980nm$ is chosen for efficient pumping because the emission cross section of the erbium ions is nearly zero for this wavelength. The spectra of the absorption cross-section (σ_a) and emission cross-section (σ_e) of the Al co-doped EDFA are shown in Fig.1. The amplified spontaneous emission noises (ASEN) are assumed to be optical beams of effective frequency bandwidth $\Delta\nu_k$ centered at the wavelength $\lambda_k = c/\nu_k$ to resolve the ASEN spectrum [7]. Computer simulation is used to determine the signal output power and noise spectrum for an EDFA. Without the FBG written in the EDFA, Fig.2 shows the optical spectra evolution of 8 channel WDM signals among transmission distance. The 8 channel WDM signals are allocated from 1532 to 1537.6 nm, the channel spacing is 0.8 nm. The signal powers are unequal and the noise is produced due to FWM. The unbalance powers of signal can be flattened by the FBGs written at the different position of EDFA. Each FBG is designed to be centered at assigned frequencies with the bandwidth 0.2 nm. The each individual FBG position should be designed so that they have a maximum average gain over the 8 channel signal and optimum gain flatness for the given input signal power level. The optimum written position of each FBG along the EDFA for gain equalization is shown in Fig.3. By using the set of FBGs shown in Fig.3 at the EDFA of 600 km, Fig.4 shows the flat signal amplification with the same conditions shown in Fig.2. On Bragg reflection, the fiber grating can equalize the channel output and filter out the noise. For the requirement of increasing the signal to noise ratio and equalizing the channel output power of EDFA, the optimum design for fiber grating is needed.

四、計畫成果自評

This project has been performed thoroughly. The results are outstanding in the respects of gain equalization of erbium doped fiber amplifier and filtering out the noise due to FWM and Raman crosstalk of WDM system.

五、參考文獻

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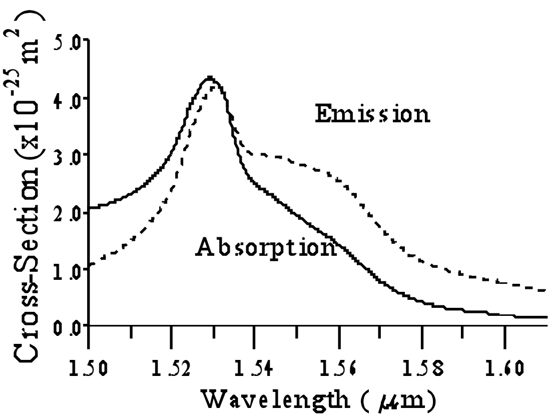

Fig.1 The spectra of the absorption cross-section (σa) and emission cross-section (σe) of the Al co-doped EDFA.

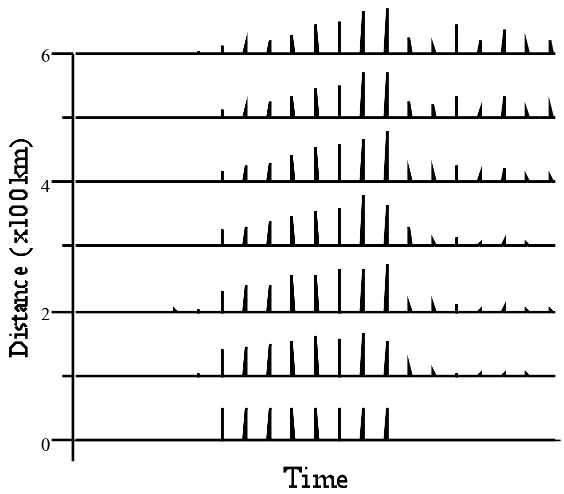

Fig.2 The optical spectra evolution of 8 channel WDM signals and among transmission distance.

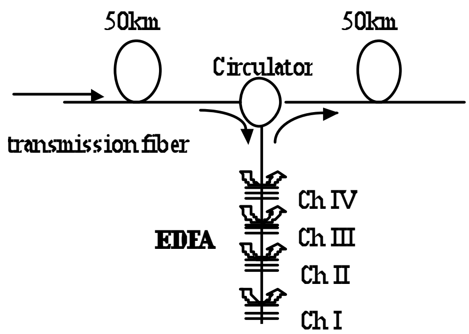

Figure 3: The System Model for WDM Configuration.

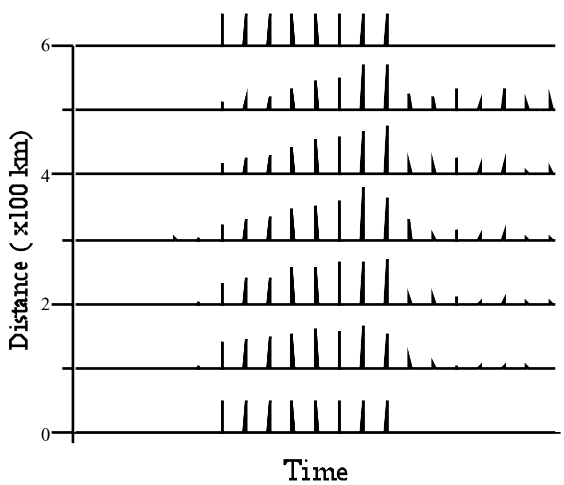

Figure 4: The flat signal amplification with the same condition shown in Fig.2.