5 GBIT/S (2 X 2.5 GBIT/S) REPEATERLESS WDM TRANSMISSION OVER 250 KM OF DISPERSION-SHIFTED FIBER USING DIRECT MODULATION

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RESUMO: Este trabalho apresenta os resultados obtidos em um experimento de transmissão óptica, a 2x2.5 Gbit/s, em dois canais multiplexados em comprimento de onda (WDM) separados por 2 (dois) nm, através de 250 km de fibra com dispersão deslocada (DSF), utilizando modulação direta nos transmissores. A sensibilidade na recepção após 250 km é comparada com aquela obtida acoplando-se o receptor diretamente ao transmissor. Não foi observada degradação apreciável na sensibilidade do receptor, demonstrando a aplicabilidade do resultado em um sistema de transmissão óptica.

ABSTRACT: We report on a repeaterless transmission of 2x2.5 Gbit/s, 2 nm spaced WDM channels over 250 km of dispersion-shifted fiber (DSF) using, as light sources, directly modulated DFB lasers. Back-to-back sensitivity was compared with 125 km and 250 km of transmission through DSF, for different transmitter power levels, and no significant power penalty was observed

Keywords: Optical Communication, Wavelength Division Multiplexing

1 - INTRODUCTION

Wavelength-division multiplexing (WDM) in long-span repeaterless transmission links is attractive due to its potential applications in submarine *festoon* systems. Intensive research has been focused on such WDM repeaterless systems using Erbium Doped Fiber Amplifiers (EDFA) as post- and preamplifiers[1]. To maximize the distances between transmitter and receivers, high launched powers are required. Unfortunately, at high fiber-input powers, signal degradation caused by fiber non

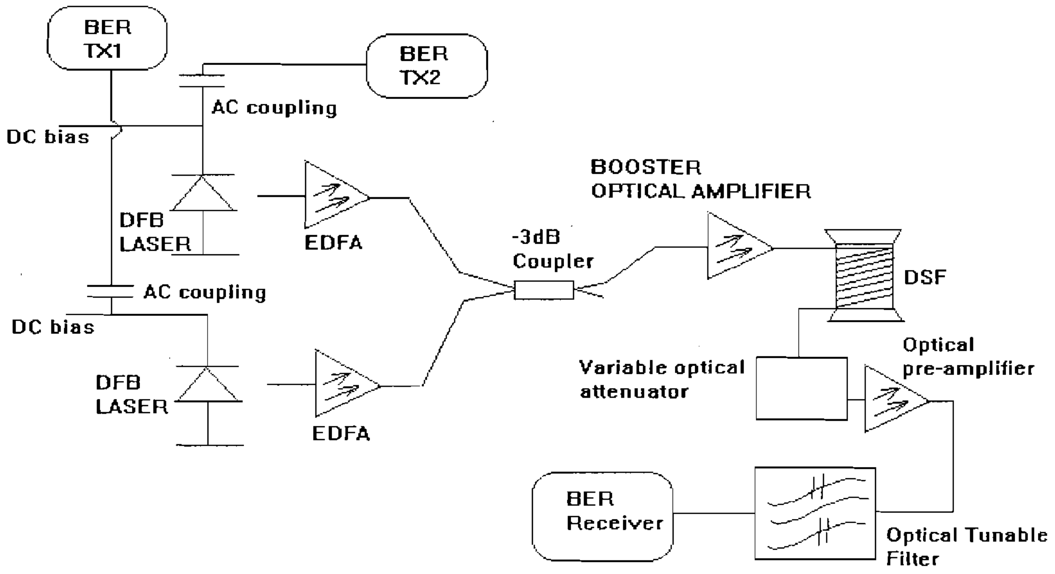

Fig 1 Experimental set-up

linear effects may limit the repeaterless span[2]. These fiber non linearities are more pronounced when narrow linewidth sources are used in conjunction with near-zero dispersion fibers[3]. Even though, in repeaterless transmission systems external modulation of the optical source has been preferred over direct modulation to reduce the influence of chromatic dispersion. The use of external modulation, in long span repeaterless optical communication system requires dithering of the lasing wavelength, to overcome stimulated Brillouin scattering (SBS). Directly intensity modulated WDM systems are very attractive due to its simplicity and can overcome the dispersion penalty by the use of a DSF. Previously, single optical carrier transmission over 310 km at 1.8 Gbit/s using DSFhave been demonstrated using direct modulation of the DFB laser [4]. This paper presents a 2 x 2.5 Gbit/s direct modulated WDM repeaterless transmission experiment through 250 km of DSF. The experiment was realized without dispersion management, setting the optical channels only 2 nm apart. No significant power penalty was observed after 250 km of DSF using the NRZ-format transmission.

2 - EXPERIMENTAL SET-UP

Figure 1 shows the experimental set-up. The signal light sources are two DFB lasers fabricated at CPqD-TELEBRÁS. The lasers are thermally stabilized and directly modulated, with an extinction ratio of approximately 10. Two independent 2.5 Gbit/s pseudo-randon NRZ sequences were used. The wavelengths are set to 1542 nm and 1544 nm with a chirped linewidth estimated to be 12 GHz. In order to reach power levels able to saturate the optical post-amplifier, both channels are amplified by two independent EDFAs. The wavelength multiplexing is obtained by a 3 dB achromatic coupler. The saturated optical output power of the post-amplifier is adjustable up to +24.3 dBm. 250 km of DSF ($\lambda o = 1548 \pm 0.5$ nm) with 0.23 dB/km attenuation was used as the transmission medium.

At the receiver, both signals are pre-amplified by a low noise EDFA, and the channel is selected by a 0.7nm, @-3 dB bandwidth optical tunable filter. The receiver front end is composed by pin photodiode and a low noise transimpedance amplifier. The sensitivity of optically pre-amplified receiver is -38dBm@ 10^{-10}.

3 - EXPERIMENTAL RESULTS AND CONCLUSION DISCUSSION :

In order to evaluate receiver degradation due to non-linear effects, we measured the BER (bit-error rate) versus sensitivity characteristics for three different transmitter power levels distributed over both channels: 14 dBm, 19.4 dBm and, 24 dBm. BER for this two-channel experiment are shown in Fig. 2 for 125 km of transmission through DSF. The back-to-back difference of 1 dB observed between channels can be traced to differences in the bias/extinction ratio settings at the LD transmitters. No significant power penalty was observed in these experiments realized without any dispersion management. Furthermore, there is no evidence of BER floor for measured BER values as low as 10^{-11} at both channels.

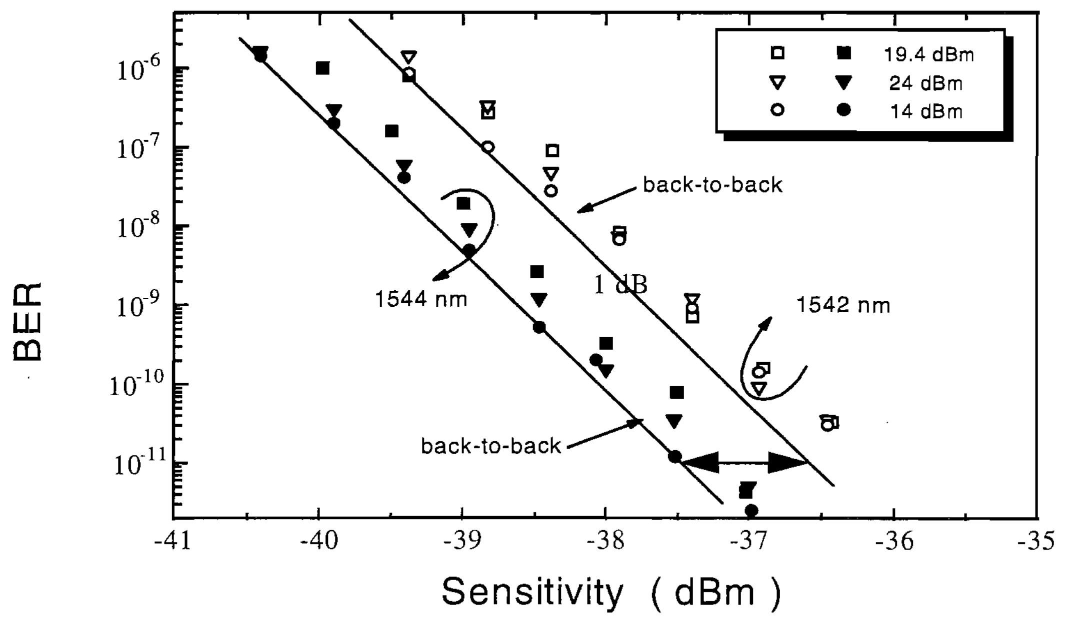

Fig. 2 BER versus receiver sensitivity for both channels at three different transmitter power levels

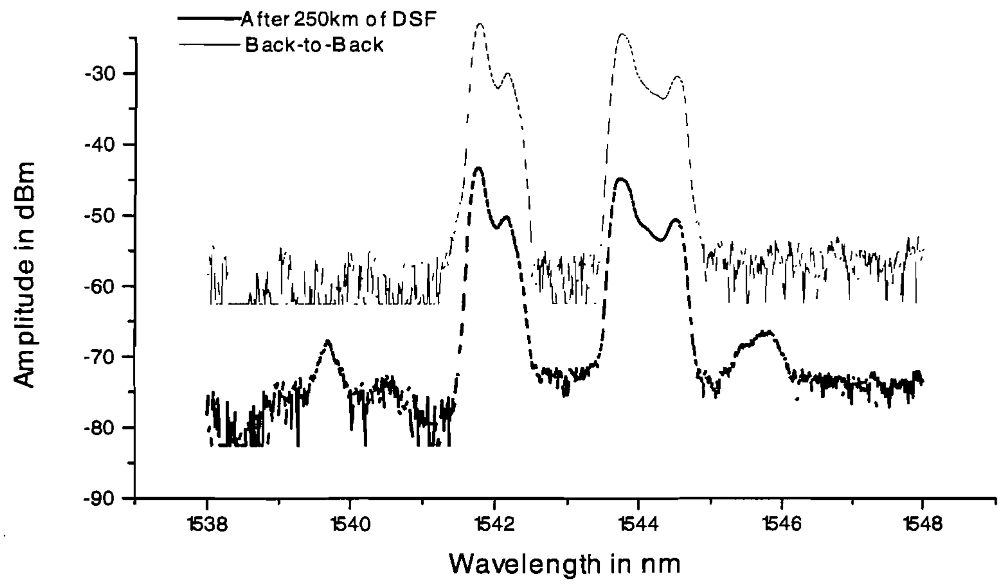

Fig 3 **Optical spectrum after 250km of propagation through DSF. The output of the booster amplifier is set to +24dBm**

Figure 3 shows the optical spectrum transmitted in both situations : over 250km of DSF and back-to-back. The four wave mixing (FWM) lines are evident in the optical spectrum obtained after of 250km of DSF. For a two wavelength WDM experiment the receiver power penalty due to FWM is negligible. The optical spectrum which travels 250km of DSF shows a low intensity band between the laser peaks. This band can be attributed to cross phase modulation (XPM)[5].

Figure 4 shows the eye diagrams for both channels after 250 km transmission. These results could be explained based on the decreasing of spectral power density. The broad linewidth of the direct modulated lasers (12 GHz) reduces the spectral power density increasing the non linear threshold for SBS, and reducing the effects of FWM.

For 22 dBm launched power per channel at the transmitter, the power budget deduced from Fig. 2 ranges from 58.5 dB (10^{-11} BER) at 1542 nm to 59.5 dB (10^{-11} BER) at 1544 nm. The total loss of the 250 km fiber spool is 57.5 dB, which demonstrates the viability for implementing such WDM links. This reported loss budget achieved without remoted pumped optical amplifiers and/or forward error correction schemes enables simple network upgrade to match traffic growth.

We transmit 2x2.5 Gb/s direct modulated lasers, in a WDM configuration, over 250 km of DSF, with 2 nm channel spacing. No significant transmitter or receiver sensitivity degradation was observed due to non linear effects as well as dispersion. The spectral linewidth broadening resulting from the transmission of chirped signals can qualitatively explain these results.

CONCLUSION

We transmit 2x2.5 Gb/s direct modulated lasers, in a WDM configuration, over 250 km of DSF, with 2 nm channel spacing. No significant transmitter or receiver sensitivity degradation was observed due to non linear effects as well as dispersion. The spectral linewidth broadening resulting from the transmission of chirped signals can qualitatively explain these results.

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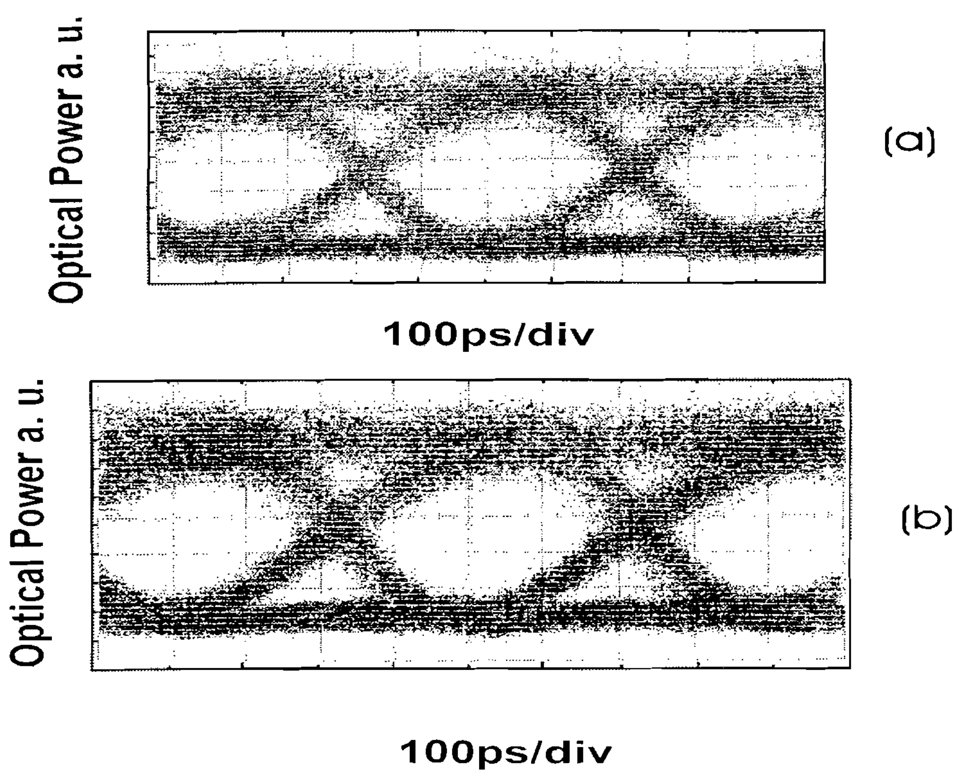

Fig 4 **Eye diagram of both channels after 250km transmitted through DSF.** (a) **1542nm,** (b) **1544nm**