10.7 Gb/s CWDM system transmission with 8 channels in 140 nm bandwidth over 120 km using two SOAs

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Abstract: We demonstrate 8-channel CWDM transmission at 10.7 Gb/s over 120 km of fiber in two different configurations using just two SOAs for wide bandwidth amplification. The total system capacity-distance product is 9.6 Tb/s-km.

OCIS codes: (060.2330) Fiber optics communications;

1. Introduction

Coarse wavelength division multiplexing systems (CWDM) have sparked interest in recent years for applications in access and metro networks that require only a few optical channels [1-4]. One of the primary limitations of unamplified CWDM systems is often received power, which may limit reach before dispersion depending on the transmitter type and bit rate. However, semiconductor optical amplifiers (SOAs) have wide bandwidths that are well-suited for some CWDM systems [5, 6] and can allow longer transmission distances in a metro or long-reach access environment. We present results here that demonstrate longer uncompensated 8-channel CWDM transmission distances at 10.7 Gb/s than have been shown to date, and we use only two SOAs for amplification, thus avoiding the complexities of hybrid SOA/Raman amplifiers. In particular, we demonstrate 8-channel (140 nm bandwidth) CWDM transmission over 120 km with two different configurations that are not dispersion limited at this distance. In one configuration, duobinary signals are transmitted over standard single-mode fiber, and in the second configuration, conventional zero-chirp non-return-to-zero (NRZ) signals are transmitted over a non-zero dispersion shifted fiber (NZ-DSF). In both configurations, two SOAs are cascaded in the system, no dispersion compensation is used, and the total capacity-reach product demonstrated is 9.6 Tb/s-km.

2. Experimental set-up and results

The basic CWDM system investigated in these experiments is an 8-channel system with wavelengths spaced by 20 nm and ranging from 1470 nm to 1610 nm. The experimental set-up is represented schematically in Figure 1. The 8 optical wavelengths are combined with a CWDM multiplexer and simultaneously modulated with a Mach-Zehnder modulator. The modulator produced either NRZ signals or duobinary signals, depending on the configuration under test. A 3-level electrical signal was generated with a 2.5 GHz low-pass filter (LPF) in the duobinary transmitter, which then was used to drive the Mach-Zehnder modulator which was biased at minimum output with a 2Vpi voltage swing. The eight channels were transmitted over 2 spans of 60 km, each of which was followed with an SOA for amplification. The fiber type used in the 60 km spans depended on the signal modulation. For NRZ modulation, the fiber was Corning® LEAF® fiber, an NZ-DSF with nominal dispersion values at 1550 nm of about 4 ps/nm/km and at 1610 nm of about 9 ps/nm/km. For the second configuration with duobinary modulation, standard single-mode fiber was used. The channels were demultiplexed with a CWDM demux, detected with a PIN photoreceiver, and the bit error rate (BER) was measured with an error detector. A pseudo-random bit sequence (PRBS) of length 2^{31}-1 was used for all measurements.

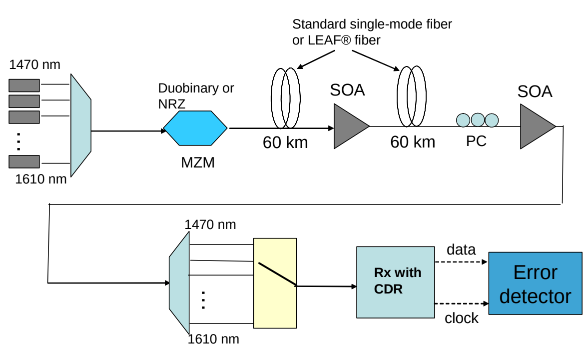


Fig. 1. Experimental set-up implemented for 8-channel CWDM experiments.

The SOAs used in these experiments are devices based on a standard buried heterostructure design utilizing a dilute mode method [7] with low noise figure (typically < 7 dB) and high 1 dB saturation power (typically > 12 dBm at 1530 nm), characteristics that make them very suitable for multi-channel amplification applications. The gain as a function of wavelength is shown in Figure 2a for the two SOAs, measured for the system channel input powers. While there is clearly a large gain variation over the 140 nm bandwidth occupied by the CWDM channels, sufficient gain is available to transmit over a 120 km distance, as will be shown shortly. The polarization dependent gain (PDG) for one of the SOA devices is shown in Figure 2b. While it is well below 0.5 dB for the design wavelengths of 1510-1570 nm, the PDG is higher for the wavelengths at both ends of the CWDM spectrum.

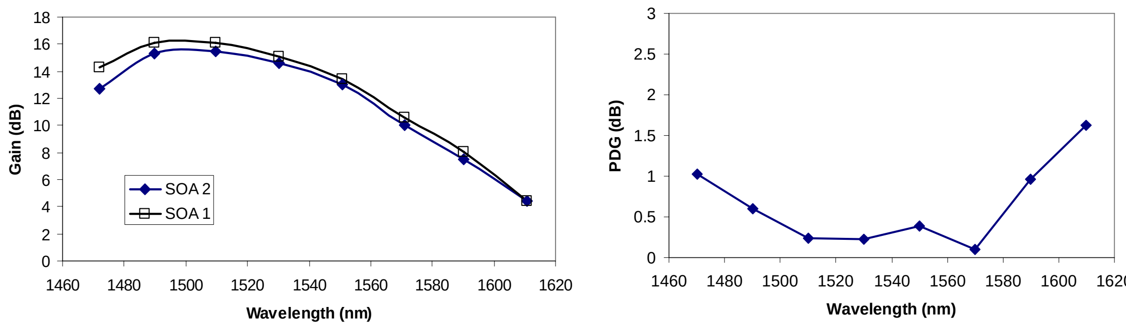
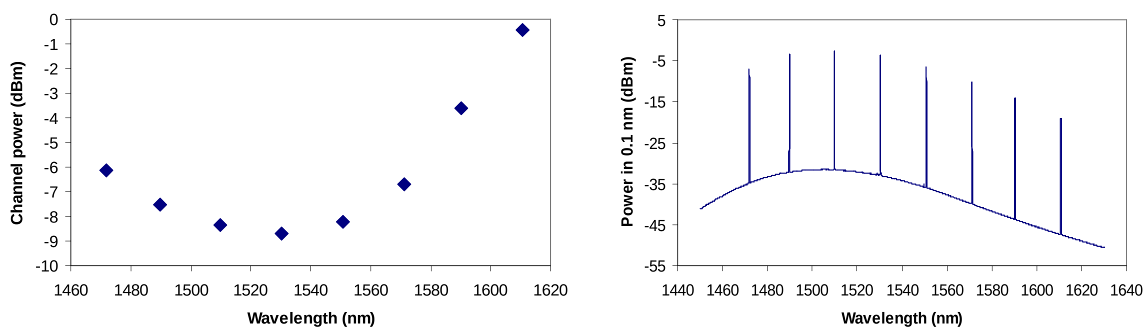


Fig. 2. (a) SOA gain as a function of wavelength for the eight CWDM channels. (b) Polarization dependent gain of one of the SOA devices.

To partially offset the gain shape, we pre-emphasized the launched CWDM spectrum into the first fiber span. The channel launch powers and the CWDM spectrum after transmission over 120 km but just prior to the CWDM demultiplexer are shown in Figure 3. The OSNR values of the channels at the receiver were in the range of 27 - 29 dB. The data shown in Figure 3 was measured for the configuration with duobinary signals over standard single-mode fiber, but were similar for the NRZ over LEAF® fiber system.

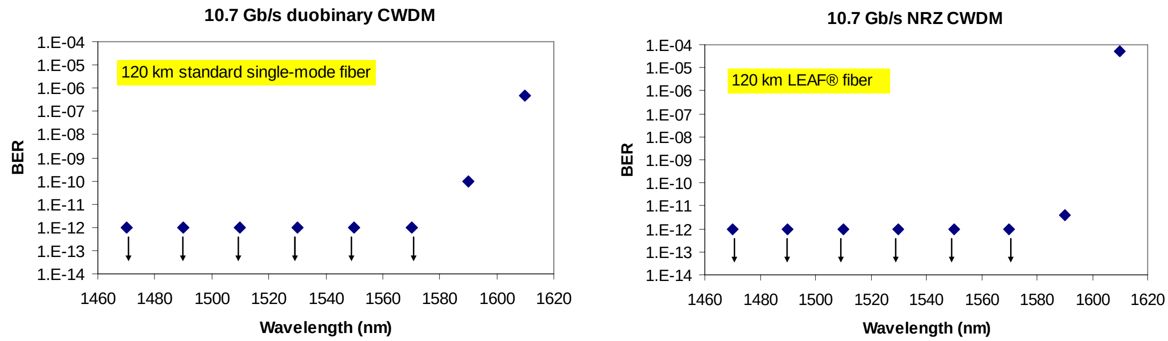


(a) (b)

Fig. 3. (a) CWDM channel launch powers. (b) CWDM spectrum (0.1 nm resolution bandwidth) after 120 km system transmission of duobinary signals over standard single-mode fiber.

The transmission results for both system configurations are shown in Figure 4, with BER values for each of the CWDM channels at the 120 km distance. In both cases, the first six CWDM channels from 1470 nm to 1570 nm were error-free and the last two channels at 1590 nm and 1610 nm had BER values that could easily be corrected to be error-free with standard Reed-Solomon (255,239) forward error correction (FEC). The 1610 nm channel was clearly the limiting channel in both cases, limited partly from accumulated dispersion but primarily by received power levels. We note that the polarization controller in front of SOA 2 in the system was adjusted in each case to maximize the received power of the 1610 nm channel, but no polarization control was employed prior to SOA 1. However, a receiver with an APD photodetector with higher sensitivity than a PIN detector would likely eliminate the need for polarization control for even the 1610 nm channel, and perhaps also the need for FEC at this distance.

The receiver sensitivity data for the 1590 nm channel in each configuration is shown in Figure 5. This data shows that the two systems have approximately the same sensitivity for high BER values >1e-5, but that the NRZ over LEAF® fiber system has a sensitivity advantage of about 2.5 dB over the duobinary over standard single-mode fiber system at a BER of 1e-10. This difference is due to the inherent back-to-back sensitivity difference between duobinary and NRZ and the different shapes of the modulation format dispersion penalty functions at the accumulated dispersion values represented by the 1200 km distance over the two different fiber types.



(a) (b)

Fig. 4. (a) BER for CWDM system with duobinary signals over 120 km of standard single-mode fiber. (b) BER for CWDM system with NRZ signals over 120 km of LEAF® fiber.

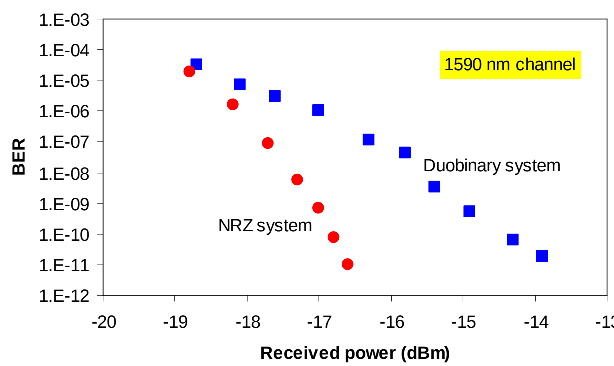


Fig. 5. BER sensitivity data for the 1590 nm channel at 120 km for the two system configurations.

3. Conclusions

We have demonstrated 10.7 Gb/s CWDM system transmission with eight channels over 120 km with two different system configurations that produce a system capacity-reach product of 9.6 Tb/s-km. In one approach, the CWDM channels were modulated with the duobinary modulation format and transmitted over standard single-mode fiber. In the second system, the signals were modulated with NRZ format and transmitted over LEAF® fiber. In both cases, two SOAs were used to at least partially compensate for transmission loss. The limiting channel in both cases was that at 1610 nm, which was primarily limited by received power level. We found that FEC would be required only for the last two channels in the channel plan in both cases. A variation to either system that may permit a longer reach would be to shift the channel plan down by 20 nm, while keeping the channel count at eight.

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