40 Gb/s uncompensated 8-channel CWDM system over 30 km of non-zero dispersion shifted fibre

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Abstract *8-channel uncompensated CWDM transmission is demonstrated with 40 and 42.7 Gb/s duobinary channels over up to 30 km of NZ-DSF. We find that standard FEC does not offer increased reach for this system.*

Introduction

Coarse wavelength division multiplexing (CWDM) systems at 2.5 or 10 Gb/s are typically power-budget limited long before dispersion impairment limitations come into play. However, dispersion plays a much more significant role at 40 Gb/s and its effect can predominate over that of receiver sensitivity. An 8-channel CWDM system at 40 or 42.7 Gb/s spanning the wavelength range of 1470 nm to 1610 nm might be expected to have a reach of ~5 km limited by dispersion at the long wavelength for non-return to zero (NRZ) signals transmitted over standard single mode fibre, an impractical length for most metro network applications. However, duobinary signals have been shown to offer significant uncompensated reach advantages over NRZ on the order of 2x-3x [1-3]. Combined with a non-zero dispersion shifted fibre (NZ-DSF) with lower dispersion than standard fibre, distances of practical interest in metro networks start to become feasible. Here we report system results from transmission experiments involving an 8-channel CWDM system using duobinary signals over an NZ-DSF. We investigate both 42.7 and 40 Gb/s results, and achieve uncompensated transmission over up to 30 km, representing a capacity-distance product of 9.6 Tb/s-km. This product has been previously demonstrated with a 10 Gb/s CWDM system using bidirectional transmission over standard single mode fibre [4]. The results presented here represent the same product for uni-directional transmission by operating at a data rate of 40 Gb/s.

Experimental configuration

The experimental CWDM set-up is shown in Figure 1. Eight laser wavelengths ranging from 1470 nm to 1610 nm, spaced by 20 nm, were combined with a CWDM multiplexer before being simultaneously modulated in an optical duobinary format by a single Mach-Zehnder modulator (MZM). The 3-level duobinary signal was created via low-pass filtering (11 GHz filter bandwidth) of the NRZ electrical signal from a pattern generator, and used to drive the MZM which was biased at the minimum with a 2Vpi amplitude swing. The pattern length of the pseudo-random bit sequence (PRBS) transmitted was 2^7-1 and the MZM was modulated with a bit rate of either 40 Gb/s or 42.7 Gb/s. The NZ-DSF employed in the experiments was low water-peak Corning LEAF® fibre. The dispersion of this fibre varies over the CWDM wavelength range from -2 ps/nm/km at 1470 nm to ~8.8 ps/nm/km at 1610 nm.

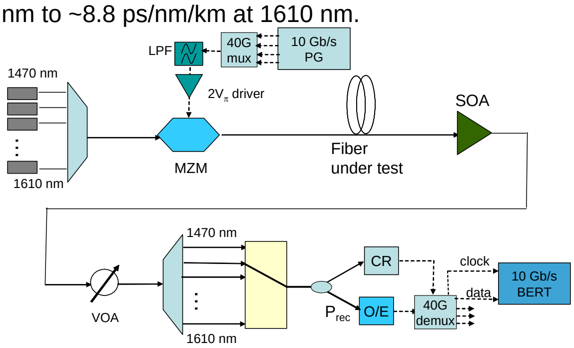

Fig. 1: Experimental set-up used in study.

A semiconductor optical amplifier (SOA) was used to provide wideband amplification to all 8 channels, partially compensating for the fibre and modulator losses. The channels were demultiplexed with a CWDM demultiplexer and a single channel was selected for measurement. The gain curve of the SOA over the CWDM bandwidth is shown in Figure 2, measured with channel output and input power levels after transmission over 25 km of fibre.

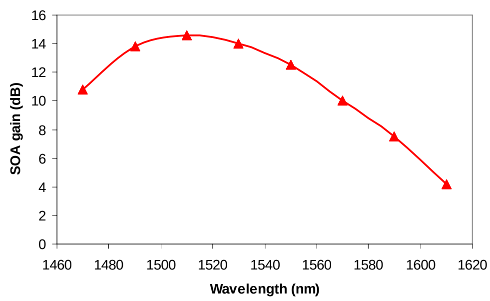

Fig. 2: SOA gain data for CWDM channels.

A variable optical attenuator (VOA) was employed before demultiplexing and detection for the measurement of some channels which experienced the greatest SOA gain. The VOA was used to keep the received power level at 0 dBm for most channels. It was removed from the set-up during measurement of those channels with signal powers < 0 dBm, which was usually the channels at 1470 nm, 1590 nm, and 1610 nm. The 40 Gb/s data stream was demultiplexed into four 10 Gb/s tributaries, one of which was measured for Q and BER. The other tributaries were verified to have similar signal quality.

Experimental results

Experiments were first conducted at a bit rate of 42.7 Gb/s, to accommodate the use of 7% overhead forward error correction (FEC). The results in Figure 3 show the channel Q values determined by variable decision threshold detection for distances of 25, 26, and 27 km. All channels have Q values above a nominal FEC threshold level of about 11.5 dB. The system performance is limited by dispersion at the longest wavelength channel at 1610 nm, with an accumulated dispersion of almost 240 ps/nm at 27 km. The 1470 nm channel has the next lowest Q value, primarily limited by received power.

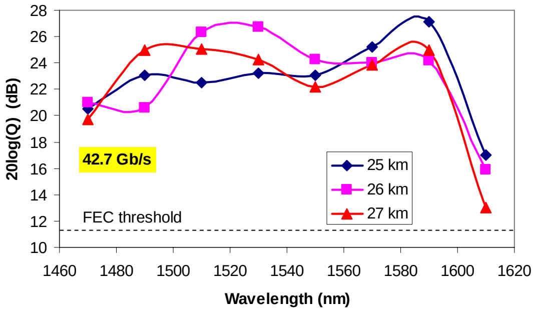

Fig. 3: 42.7 Gb/s channel Q values.

We next measured the power penalties for all 42.7 Gb/s CWDM channels at a BER of $1x10^{-6}$ by measurement of the required received powers in the back-to-back condition and after transmission over 25 km of LEAF fibre. The results are shown in Figure 4. All channels show a zero or negative power penalty at this distance except for the 1610 nm channel, which has a 4 dB penalty.

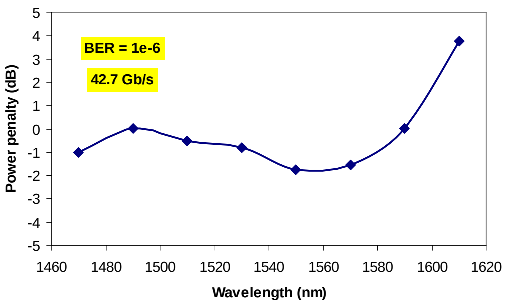

Fig. 4: 42.7 Gb/s channel power penalties at 25 km.

The power penalties of the two end wavelengths at 1470 nm and 1610 nm are shown in Figure 5 as a function of transmission distance. The 1610 nm channel exhibits a negative penalty out to a distance between 15 and 20 km, after which it becomes positive due to eye closure from dispersion. The 1470 nm channel has negative penalty for all distances out to the maximum measured. The penalty data in Figures 4 and 5 both reflect the characteristic of duobinary signals for which the eye opening increases for moderate amounts of accumulated dispersion before closing again when the dispersion becomes too large.

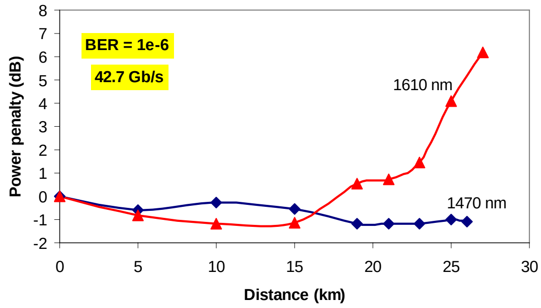

Fig. 5: Power penalties at 1470 nm and 1610 nm as a function of distance at 42.7 Gb/s.

Finally, we repeated the Q measurements at a bit rate of 40 Gb/s to compare to those at 42.7 Gb/s. At 40 Gb/s, the required Q value for error-free transmission would be 18 dB, while with FEC at 42.7 Gb/s, the raw Q need only be ~11.5 dB. Figure 6 shows the Q values vs. distance for the limiting 1610 nm channel at both bit rates. The 40 Gb/s system reaches 30 km at the nominally required Q, while the 42.7 Gb/s system reaches ~27 km. Thus FEC does not appear to lead to increased reach in this system.

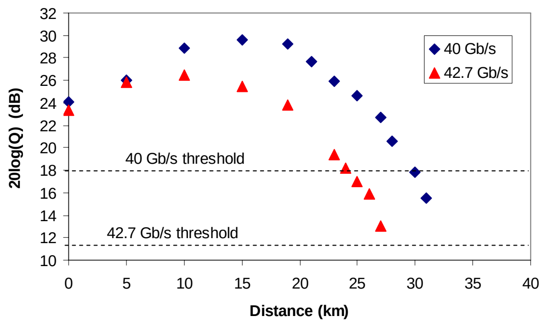

Fig. 6: 40 and 42.7 Gb/s reach at 1610 nm.

Conclusions

We have demonstrated a 40 Gb/s CWDM system using duobinary signals over LEAF® fibre, assisted with a broadband SOA. The uncompensated capacity-reach product shown was up to 9.6 Tb/s-km at a bit rate of 40 Gb/s. The use of standard FEC was shown to offer no reach advantage.

References

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