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ASSESSMENT OF SIGNAL QUALITY IN 10 Gbit/s ALL-OPTICAL NETWORKS WITH WAVELENGTH CONVERTERS

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Abstract: Detailed modelling is used to assess the performance of an all-optical network. We predict that more than 10 all-optical cross connects interconnected by dispersion compensated single mode fiber can be cascaded at 10 Gbit/s.

Introduction

For the successful implementation of future all-optical networks with optical cross connects (OXCN), the interaction between fiber dispersion and the OXCNs is important. In particular, it is expected that wavelength converters will be included in the OXCNs as they improve traffic performance and ease network management [1]. Hence, the interaction between the wavelength converters and the fiber transmission path is of interest.

Here this important issue is addressed theoretically for an 8×10 Gbit/s WDM network. We show that by precisely adjusted dispersion all-optical networks of Pan European scale can be feasible.

Network architecture

Figure 1 shows the OXCN investigated in the ACTS project OPEN [2] and also in this work. It consists of a space switching stage and a wavelength converter stage. The space switching is of the broadcast and select type, using semiconductor optical amplifiers as gates. The gates have the advantage a high on-off ratio that eliminates interferometric cross-talk.

The wavelength converter stage consists of tuneable Fabry-Perot filters with 1 nm bandwidth and wavelength converters of the interferometric type.

Fig. 1: OPEN OXCN architecture based on broadcast and select principle

They employ semiconductor optical amplifiers (SOAs) as optically controlled phase-shifters in a Mach-Zehnder configuration [3, 4]. Converters based on this principle have the

capability of pulse re-shaping due to their sinusoidal transfer function [5]. The transfer function also results in a redistribution of the noise, thereby significantly reducing its impact [6].

Fig. 2: Link architecture.

Figure 2 shows the studied optical path. A number of links are cascaded, each formed by an OXCN followed by four spans of dispersion compensated standard single mode fiber (SSMF). Each fiber span has 80 km SSMF with a group velocity dispersion of 17 ps/km/nm and a length of DCF fiber with a dispersion of -80 ps/km/nm. We assume ideal flat gain amplifiers to compensate for losses. Eight wavelength channels at 10 Gbit/s spaced by 200 GHz with λ_1 located at 1547.72 nm are considered.

Model

To assess the transmission performance, detailed time domain models for WDM fiber transmission and interferometric wavelength converters are employed. Each converter in the OXCNs is adjusted to give the same extinction ratio at the output of the OXCN as at the input. The IWCs are operated non-inverting, and hence, the output signal has a chirp, which gives an initial pulse compression in SSMF [7]. An important difference between OXCNs with and without IWCs is the pulse reshaping capabilities. With no IWCs in the OXCNs an optimisation of the dispersion compensation scheme must be performed on the basis of the total transmission distance. With IWCs this optimisation can be performed on a link-by-link basis.

To determine the optimum length of the dispersion compensating fiber, a transmission simulation on one link was performed for different lengths of the DCF, both with and without IWCs. The penalty versus the DCF length is seen in Fig. 3.

Fig. 3: Penalty as function of dispersion compensating fiber length without (a) and with (b) IWCs in the OXCNs.

For a single link length of 320 km the tolerance for the DCF length in each span is 1.6 km, whereas this has shrunk to 400 m for 4 cascaded links (1280 km). Hence, the length of the dispersion compensating fiber becomes a critical parameter for longer transmission distances. With IWCs in the path, the tolerance of the DCF length is significantly wider, as seen in Fig. 3(B). It is important, however, that one does not select a DCF length resulting in pulses becoming too narrow, as the pulse width of the compressed pulses at the input of the succeeding OXCN to a certain extent is maintained at the output. This results in an increasing impact from the dispersion and, hence, a quick signal deterioration [7]. Consequently, a DCF length of 16.8 km is chosen in the case with IWCs in the OXCNs..

Results and discussion

Figure 4 shows the penalty for the 8 transmitted channels versus the number of cascaded OXCNs both without (A) and with (B) interconnecting fiber.

Fig. 4: Penalty versus link number for the 8 transmitted channels without (A) and with (B) interconnecting fiber.

Even though the IWCs initially are adjusted for same performance, they suffer from a slight wavelength dependence in pulse shape and chirp. This has increasing impact in a cascade. As clearly seen in Fig. 4 (A) where the penalties for channel 1 and 8 are 1.3 dB and 4.2 dB, respectively, after 10 cascaded OXCNs. In this case the cascability is limited by the modulation bandwidth of the converters. However, the limited modulation bandwidth can be compensated by pulse compression during transmission by choosing the proper length of DCF. This is shown in Fig. 4 (B). For DCF lengths of 12.4 and 15 km a quick deterioration is observed, whereas for 16.8 km only a slight pulse compression is experienced. This compensates for the pulse broadening during conversion. Therefore the pulse quality is maintained even after 10 links. Additionally, the wavelength

dependence of the conversion is compensated by the fiber links, since broader signal pulses will experience a larger pulse compression compared to more narrow pulses. The simulated eye diagrams after the 1st, 5th and 10th OXCN for channel 1 (top) and channel 8 (bottom) are shown in Fig. 5. Only a small difference between the channels is observed. Jitter is seen as the limiting factor for cascability.

Fig. 3: Eye diagrams at the output of OXCN no. 1, 5 and 10 for channel 1 (top) and channel 8 (bottom).

Conclusion

A detailed time domain model has been used to investigate an all-optical network employing IWCs. Without fiber between the OXCNs, a small number of 5 OXCNs could be cascaded due to limited modulation bandwidth of the IWCs. It was also observed that a slight wavelength dependence of the IWCs resulted in a penalty difference. Introducing fiber between the OXCNs, both the wavelength dependence and the modulation bandwidth limitation was compensated with the length of the DCF as a crucial parameter for optimum performance. For a DCF length of 16.8 km more than 10 OXCNs interconnected by a total of 3200 km standard single mode fiber could be cascaded.

Consequently, the all-optical network concept utilising optical OXCNs with IWC is predicted applicable on a Pan European scale.

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