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Transmission enhancement by deployment of interferometric wavelength converters within all-optical cross connects

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Wavelength-division multiplexing (WDM) networks are expected to utilize all-optical cross connects (OXCN) for signal routing. Because a signal path is likely to contain a number of OXCNs, their cascadability is essential. Furthermore, because wavelength converters in the OXCNs improve traffic performance and ease network management, their cascadability, in particular, is important. Using interferometric wavelength converters (IWCs) we have previously demonstrated experimentally a cascade of 10 converters at 10 Gbit/s with <2-dB penalty. In this paper we analyze the cascadability limitations of OXCNs deploying IWCs.

The wavelength converters used in the experiments and in this analysis are interferometric wavelength converters, where semiconductor optical amplifiers (SOAs) are used as optically controlled phase shifters in a Michelson configuration. Converters based on this principle have the capability of pulse reshaping due to their sinusoidal transfer function and small chirp.

Importantly, when cascading nonlinear devices such as IWCs, the resulting transfer function is not the product of the individual IWC transfer functions. Here we show by detailed modeling that IWCs are cascadable in large numbers (>30) at 10 Gbit/s and their reshaping capability enhances the possible transmission distance when interconnected by nondispersion-shifted (NDS) fiber. The modeling shows excellent agreement with experiment.

In networks where the OXCNs are interconnected by dispersion-compensated fiber (zero accumulated dispersion between OXCNs), pulse distortion along the signal path arises during conversion. The effect of this pulse distortion is seen in Fig. 1, where the penalty for a
10-Gbit/s signal as function of the number of cascaded IWCs is shown. For a bias current of 100 mA (modulation bandwidth of each IWC \( \sim 28 \) GHz) five converters can be cascaded with 1-dB penalty. Increasing the bias current to 150 mA and thereby the modulation bandwidth to \( \sim 40 \) GHz the number of possible converters is \( \geq 50 \). The effect of insufficient IWC bandwidth is seen in Fig. 2, which illustrates a part of a PRBS after 0, 2, 5, and 10 converters for SOA currents of: A) 100 mA and B) 150 mA. Clearly, the IWCs biased with 100 mA are too slow resulting in a penalty of \( > 5 \) dB after 10 converters, whereas the converters biased with 150 mA can follow the 10 Gbit/s signal.

In case of imperfect dispersion compensation between the converters, pulse distortion also arises during fiber transmission. However, when transmitting converted signals through NDS fiber, the small chirp of the IWCs results in an initial pulse compression, which can be equalized by the converters. This reshaping requires only a moderate bandwidth of the IWCs as shown in Fig. 3, that gives the penalty as function of the number of converters with the accumulated fiber dispersion as parameter. The number of IWCs possible for a bias current of 100 mA (solid lines) is enhanced from 5 to 9 with the insertion of 30 km of NDS fiber. Increasing the NDS fiber span increases the pulse distortion beyond IWC reshaping capability and a fast deterioration is observed. No enhanced transmission distance is obtained by increasing the bias current to 150 mA (dashed lines), because the narrowed pulses are maintained at the output of the converter giving rise to an increasing impact from fiber dispersion throughout the link.

In summary, we have shown that interferometric wavelength converters with adequate bandwidth improve transmission performance. We predict that more than 30 converters can be cascaded at 10 Gbit/s.