DTU Library

Assessment of dual-stage wavelength converter in OXC at 20 Gbit/s

Kloch, Allan; Hansen, Peter Bukhave; Wolfson, David; Danielsen, Søren Lykke; Stubkjær, Kristian; Emery, J. Y.; Pommereau, F.; Renaud, M.; Schilling, M.

Published in:
Optical Communication, 1998. 24th European Conference on

Link to article, DOI:
10.1109/ECOC.1998.732766

Publication date:
1998

Document Version
Publisher's PDF, also known as Version of record

ASSESSMENT OF DUAL-STAGE WAVELENGTH CONVERTER IN OXC AT 20 Gbit/s

A. Kloch (1), P.B. Hansen (1), D. Wolfson (1), S.L. Danielsen (1), K.E. Stubkjaer (1), J.Y. Emery (2), F. Pommereau (2), M. Renaud (2) and M. Schilling (3)

(1) Technical University of Denmark, Bldg. 348, DK-2800 Lyngby, e-mail: ak@emi.dtu.dk
(2) OPTO+, Groupement d'intérêt Economique, Route de Nozay, F-91460 Marcoussis, Alcatel Corporate Research Centre
(3) Alcatel Telecom Research Division, Lorenzstr. 10, D-70435 Stuttgart, Germany

Abstract: 20 Gbit/s dual-stage wavelength conversion to the same wavelength is realised. The converter and an optical gate form a path through the OXC considered in the European ACTS project OPEN and are operated with a penalty of only 2.5 dB.

Introduction

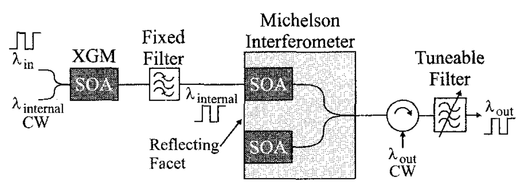
Tomorrow's demand for high capacity networks requires that the optical cross-connects (OXCs) considered today must be upgraded to higher bit rates. In wavelength division multiplexed (WDM) networks wavelength converters enable dynamic allocation of bandwidth. Furthermore, interferometric wavelength converters are of special interest because they also offer regeneration and noise suppression. Previous experimental results involving interferometric wavelength conversion at 20 Gbit/s (or higher) have been based on the Michelson interferometer. This structure does, however, not allow conversion to the same wavelength. To overcome this drawback of the interferometric Michelson converter we use a dual-stage converter with superior system performance at 20 Gbit/s and capable of the normally troublesome conversion to the same wavelength. The feasibility of the dual-stage converter in a network perspective is demonstrated by inserting an optical gate before the dual-stage converter thereby realising a path through the OXC proposed in the European ACTS project OPEN (Optical Pan-European Network). A total penalty of only 2.5 dB at 20 Gbit/s is obtained for traversing the entire OXC where conversion to the same wavelength is carried out.

Dual-stage wavelength converter

The dual-stage converter is shown schematically in Fig. 1. The first of the two stages is based on cross-gain modulation (XGM) in a semiconductor optical amplifier (SOA) whereby conversion from an incoming network wavelength, λ_{in}, to an internal wavelength, $\lambda_{internal}$, is accomplished. The co-directional conversion scheme is used for the XGM conversion. Consequently, a fixed filter is required at the output to remove the remaining signal at λ_{in} before the second converter stage, which is based on cross phase modulation (XPM) of SOAs in a Michelson interferometer. Here, wavelength conversion from $\lambda_{internal}$ to λ_{out} is accomplished according to the principle described in [3] and sketched in Fig. 1.

The dual-stage converter has several advantages. The XGM converter yields simple and polarisation independent operation. Furthermore, requirements to power levels are relaxed as the XGM converter offers a high input power dynamic range (>5 dB at 10 Gbit/s) [1]. Normally, the XGM converter has two drawbacks: (i) chirped output signals and (ii) signal deterioration for conversion to longer wavelengths.

Fig. 1: Dual-stage wavelength converter

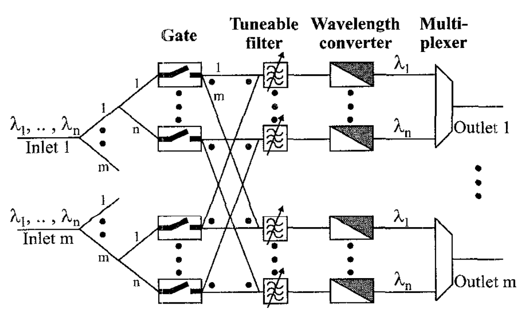


As the XGM converter is followed by another converter capable of conversion to longer wavelengths these drawbacks will not influence the performance of the dual-stage converter. This is assured by choosing the internal wavelength shorter than the shortest of the network wavelengths. After the XGM converter the dual-stage converter exploits the excellent chirp characteristics of the XPM converter together with its capability to regenerate the extinction ratio.

OPEN OXC

A path through the OXC proposed in the OPEN project is implemented to demonstrate the feasibility of the dual-stage converter. The OPEN OXC is designed for a WDM network interconnecting major European cities [2] and shown as a schematic in Fig. 2 with m in-/outlets each with n network wavelengths. The first part of the OXC forming a space switching stage consists of passive splitters, an array of

Fig. 2: OPEN OXC

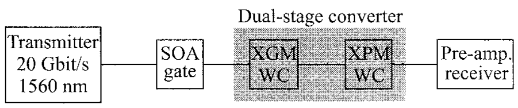


gates and combiners. The gates are based on SOAs offering a high on/off ratio (40-50 dB) and a high gain (30 dB). After the space switching stage tuneable filters are used to select the desired wavelength channel. Finally, interferometric wavelength converters with fixed output wavelengths allow for multiplexing the selected channels.

Experimental set-up

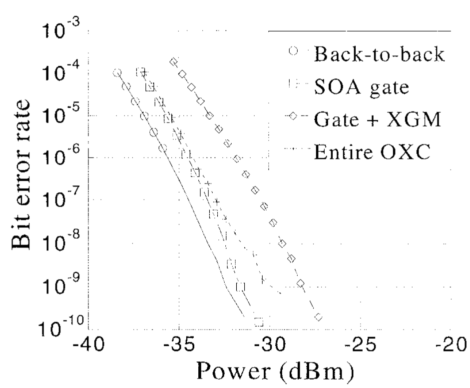
As seen from Fig. 2 a path through the OPEN OXC basically consists of an SOA gate and a wavelength converter capable of conversion from any of the network wavelength to a fixed network wavelength. Consequently, the capability of conversion to the same wavelength is required. An experiment as sketched in Fig. 3 is therefore carried out.

Fig. 3: Set-up for OXC experiment



The 20 Gbit/s modulated light at 1560 nm is transmitted through an SOA gate, converted to 1555 nm in the XGM converter and converted back to 1560 nm in the XPM wavelength converter. Hereby, the difficult conversion to the same wavelength is demonstrated. Finally, a pre-amplified receiver containing demultiplexing from 20 Gbit/s to 2×10 Gbit/s is used to obtain bit error rates at 10 Gbit/s. 20 Gbit/s eye diagrams are recorded with a 32 GHz photodiode and a 50 GHz sampling oscilloscope.

Fig. 4: Bit error rates measured through the OXC



The bit error rates measured through the OXC are shown as Fig. 4. As seen the gate causes a negligible penalty (<1 dB) at a bit error rate of 10^{-9}, whereas the additional penalty for the XGM converter is about 3.5 dB. The high-speed regenerative XPM converter improves the signal quality thereby reducing the penalty for the entire OXC to only 2.5 dB. Corresponding eye diagrams are shown in Fig. 5. Comparing the two top eye diagrams it is seen that only a small deterioration is caused by the gate. This is in good agreement with the measured bit error rates. The clear and open eye diagram obtained after the XGM converter clearly demonstrates that the penalty for inserting the XGM converter is caused by extinction ratio degradation. Due to the steep transfer function of the following XPM converter the extinction ratio is enhanced almost to the original level. Thereby the penalty for inserting the dual-stage converter is kept below 2 dB.

Another way to perform conversion to the same wavelength in interferometric structures is by using the counter-directional scheme in a Mach-Zehnder interferometer. However, the counter-directional scheme causes jitter and furthermore the modulation bandwidth is reduced compared to the co-directional scheme [3]. A dual-stage converter can also be assembled by concatenating two interferometric Michelson wavelength converters which can be accomplished with negligible penalty [4]. However, the control of two interferometers is more complex and does not offer the large input power dynamic range as the dual-stage converter demonstrated here.

In addition to conversion to the same wavelength the dual-stage converter also offers the possibility of 3R regeneration as described in [5].

Another application of the dual-stage converter is in an alternative OXC design [1] where the internal wavelengths (see Fig. 1) are used for routing.

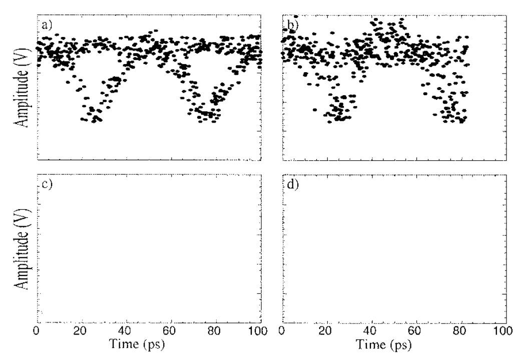
Conclusion

A dual-stage converter consisting of an XGM and an XPM converter capable of conversion to the same wavelength has been assessed in an OXC experiment. By placing an SOA gate before the dual-stage converter a path through the OXC considered in the EU-project OPEN is assessed at 20 Gbit/s. The total penalty for the path is only 2.5 dB for conversion to the same wavelength.

Acknowledgements

The European ACTS project OPEN AC066 is acknowledged for partly supporting this work.

Fig. 5: 20 Gbit/s eye diagrams after transmitter (a), after gate (b), after XGM (c) and after MI (d)



References

/1/ B. Mikkelsen et al., Proc. of ECOC´97, Paper Tu4A.2, pp. 2.245-2.248, Sept. 1997.

/2/ M.W. Chbat et al., Proc. of ECOC´96, Paper WeP.11, pp. 3.253-3.256, Sept. 1996.

/3/ C. Joergensen et al., Selected Topics in Quantum Electronics, Vol. 3, No. 5, pp. 1168-1180, Oct. 1997.

/4/ P.B. Hansen et al., "20 Gbit/s straight line cascade of two interferometric wavelength converters", submitted to OECC'98, Chiba, Japan, July 1998.

/5/ B. Lavigne et al., Proc. of OFC'98, Paper ThO7, pp. 324-325, Feb. 1998.