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Experimental characterisation of wavelength conversion at 40Gb/s based on electroabsorption modulators

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Abstract *The optimum operation point for high-speed wavelength conversion in electroabsorption modulators is investigated with respect to conversion efficiency and wavelength chirp. In particular, pump power, reverse bias and probe wavelength are found to be important operation parameters.*

Introduction

The electroabsorption modulator (EAM) has proven to be a versatile component in ultra fast WDM and OTDM systems with its ability to perform several different functionalities, yet remaining a simple structure. Recently, all-optical functionalities based on cross-absorption modulation (XAM) have been shown to possess certain regenerative properties, resulting in improvements of receiver sensitivity [2] and in transmission performance [1, 3] upon wavelength conversion. Furthermore, high-speed all-optical demultiplexing based on XAM has been demonstrated [2, 4].

In this paper, with focus on wavelength conversion using EAM, the influence of some basic characteristics, including pump light power, reverse bias of the converter and probe light wavelength, is experimentally investigated on both the wavelength-converted light itself and its chirp performance. As a result of this investigation a higher pump power (up to 20 dBm) and a relatively larger reverse bias (-2.5 V) are preferred for obtaining both larger extinction ratio (ER) and lower chirp of the converted signal. As to the probe wavelength, which is so far optional within the whole C-band, conversion to longer wavelength relative to the pump shows higher conversion efficiency and smaller dc-component, while conversion to shorter wavelength exhibits lower frequency chirp. This suggests the possibility of optimising the EAM for particular systems applications.

Experimental procedure

The experimental set-up is shown in figure 1. An erbium fibre ring laser (EFRL), working at 1552nm, generates short optical pulses at 10GHz which are data modulated by a MZ modulator and then optically multiplexed to 40Gb/s, to be used as the pump signal. The probe light, generated by a tunable laser (TL), is injected into the EAM together with the pump signal, and through the process of XAM the pump data signal is transferred to the probe. The converted signal is afterwards demultiplexed back to 10Gb/s by a non-linear optical loop mirror (NOLM) which consists of 500m highly non-linear dispersion-shifted fibre (HN-DSF).

The EAMs used in this paper are MQW devices with 10-15 quantum wells and with small electrical capacitance. The devices are provided by Giga-An Intel Company.

In figure 1 the eye diagram of the original signal at 1552nm and that of the converted signal at 1561nm are depicted, together with the signal demultiplexed by the NOLM. In this case the receiver sensitivity for 10^{-9} BER is about –26.6dBm, which can be further improved by optimising the receiver and the NOLM.

Based on this set-up, by varying the pump power as well as the reverse bias of the EAM and the probe wavelength, a clear picture of the EAM-based wavelength conversion is revealed.

Pump power and bias dependence

The XAM occurring in an EAM can be explained by the fact that when two beams, referred to as the pump and probe beam, are launched into an EAM, the photon-generated carriers due to the absorption of the pump beam of higher power have an effect of screening the electric field imposed on the device, thereby lowering the probe absorption. This results in a higher output of the probe in the presence of a logic "1" in the data-encoded pump signal, thus transferring the data to the new (probe) wavelength. The performance of the wavelength conversion in an EAM is thus directly related to the power difference between "1" and "0" levels of the pump.

In figure 2 we compare two cases with pump power of 16 dBm and 20 dBm, the eye diagrams show that higher pump power leads to a better eye-opening, suggesting that the XAM process is more efficient at this pump level. The BER quoted above is obtained at 20dBm while it wasn't possible to achieve such a low BER at a pump power level of 16dBm.

The dependence of bias voltage of the EAM is also studied at 16dBm pump light. As shown in figure 3 under fixed pump power higher reverse bias is beneficial. Lower bias thus leads to a long "tail" in the eye diagram, which is attributed to a longer carrier recovery time under weak electric field.

It should be noted that although the present results indicate higher pump power to be beneficial, one should be careful in the use of excessive pump power levels. Since the number of photon-generated carriers increase with pump power, the recovery time may be increased. This may be counterbalanced by the use of a higher reverse bias, which may, however, also increase the insertion loss of the device. Beyond this the reliability of an EAM under such extreme conditions also needs consideration.

With reference to an earlier experiment [5], the frequency chirp of the wavelength converted signal also depends on the

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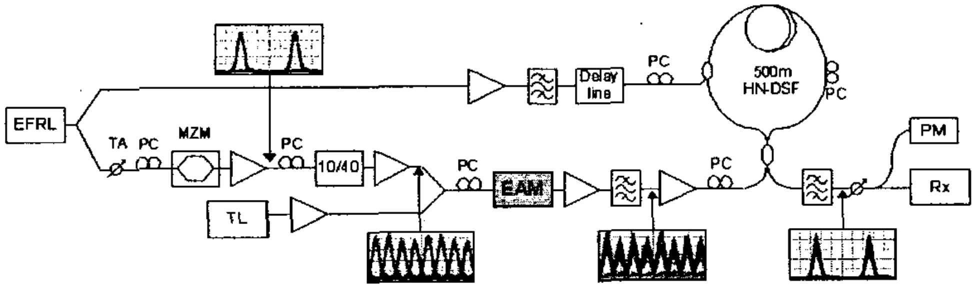

Fig 1. *Experimental set-up. EFRL: Erbium fibre ring laser, TA: Tunable laser, PC: Polarization control, TL: Tunable laser*

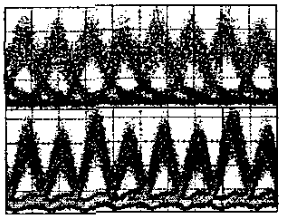

Fig 2. *The converted signal with pump power at 16dBm(upper) and 20dBm(lower)*

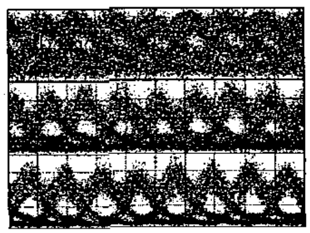

Fig 3. *The converted signal under 16dBm pump power with reverse bias at –1.5 V(upper), -2.0 V(middle) and –2.5 V(lower).*

bias. As shown in figure 5 (a), higher bias has lower or even negative chirp α-parameter which is desirable for long haul lightwave systems when dispersion compensation is considered.

Probe wavelength dependence

The performance at various probe wavelength has also been investigated and the sample results are shown in figure 4. Generally the original signal at 1552 nm can be converted to any wavelength ranging from 1537 nm to 1664 nm, and in all cases clear and open eyes are observed. This suggests that the EAM-based wavelength conversion has a wide tunable range.

It is, however, found that at 1537 nm and 1542 nm an appreciable dc-offset exists, which limits the achievable extinction ratio. In contrast, longer wavelengths of 1561 nm and 1564 nm don't exhibit a large offset.

The dc component reflects the fact that a part of the probe beam passes though the device without being modulated due to an insufficient XAM effect.

On the other hand referring to previous chirp measurement [5], as shown in figure 5 (b), shorter wavelength has lower chirp

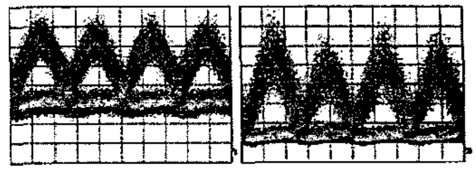

Fig 4. *The converted signal at 1537 nm(left) and 1561 nm(right)*

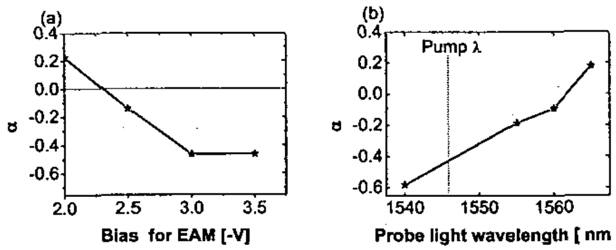

Fig 5. *α-parameter versus (a) bias and (b) wavelength.*

parameter. Here the fibre-response method developed by Devaux [6] for measuring the e/o chirp was modified to measure the o/o chirp α-parameter.

Conclusions

We have experimentally characterised the dependence of EAM-based wavelength conversion at 40Gb/s on several key factors. It is shown that higher pump power and larger reverse bias are generally desirable. Longer probe wavelength leads to high extinction ratio in contrast with shorter wavelengths, while the latter is preferred for low-chirp operation.

References

1 T. Otani et al., *J. Lightwave Technol.*, vol. 20, pp. 195-200, (2002).
2 L.K. Oxenløwe et al., *ECOC 2001*, paper Th. B. 2.5, (2001).
3 P. Cho, et al., *Photon. Technol. Lett.* 12(2), 205-207 (2000).
4 K. Shimomura et al., *ECOC 2000*, paper 9.4.5, (2000).
5 L. Xu et al., *ECOC 2002*, paper P1.26 (2002).
6 F. Devaux et al., *J. Lightwave Technol.*, vol. 11, pp. 1937-1940, (1993).