

Characterization of an All Optical Label Swapping Node for IP over WDM

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We present results of the experimental characterization of an optical node supporting swapping of IM/FSK labeled signals. Specially, we focus on the performance of a MZI wavelength converter based on cross-phase modulation (XPM). Simulation results and measurement of the chirp of converted signals operating at 2.5 Gb/s and 10 Gb/s are presented. Conclusions are drawn regarding the implications of the wavelength converter performance on the quality of the label swapping and signal data integrity.

Introduction

By putting IP packets directly into WDM channels and by bypassing electronic processing in the network nodes, optical packet routing can significantly increase the network throughput. The main objective of the IST-STOLAS (switching technologies for optically labeled signals) project is to improve the throughput of packet-switched networks by novel optical routing techniques based on optical labeling [1]. The proposed signal labeling is based on orthogonal modulation formats, IM at 10 Gb/s for the payload and FSK at 155 Mb/s for the header. In gigabits-per second long-distance optical telecommunication systems the presence of wavelength chirp may limit the transmission distance and the bit rate. In the STOLAS concept, chirp may degrade the performance of the IM/FSK label information if its magnitude is substantially large. Particularly when the chirp is larger than the frequency deviation between the two frequency tones of the FSK signal. Wavelength converters are fundamental building blocks of the optical label swapping node proposed within the STOLAS project[1]. In this paper we present a simulation and experimental study of the chirp properties of wavelength converted signals and its implications for the combined IM/FSK modulation format to label optical signals.

Simulations

To investigate the performance of a MZI wavelength converter based on XPM, we have performed simulations in VPI Transmission maker software. The schematic diagram of the simulations is shown in figure 1. The results of analyzing the FSK signal are shown in figure 2 and 3. In figure 2 we can see a pattern dependence on the amplitude of the FSK signal. This is due to the payload bit stream at a higher bit rate: 10 Gbit/s. During the transmission of one label bit there are 64 payload bits simultaneously sent with the same light wave. Thus depending on the number of ones in those 64 bit sequence of the payload the FSK bit will have a variable power level. This power dependence of a binary "one" can also be clearly seen in

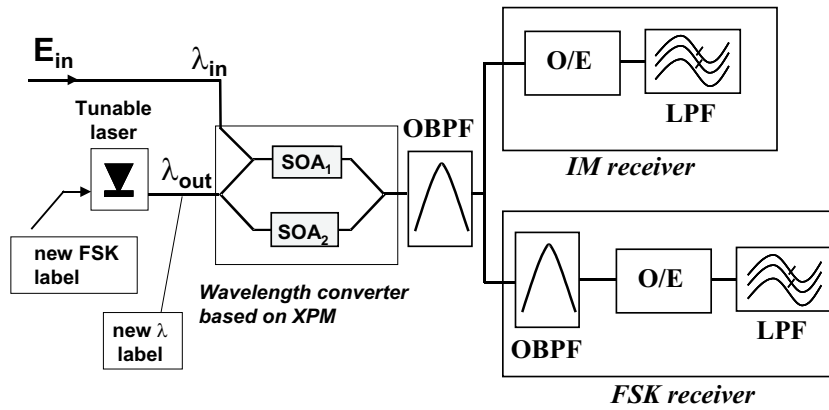


Figure 1: Schematic diagram of orthogonal labeling in an All Optical Label Swapping (AOLS) Node.

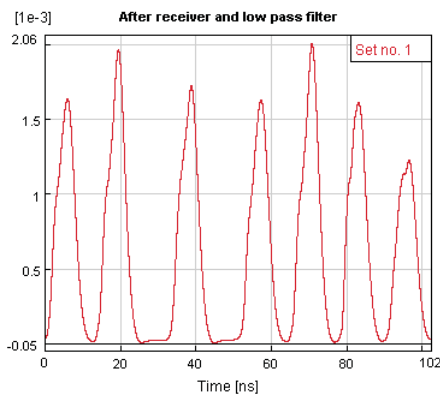


Figure 2: The FSK output data, at 156.25 Mb/s.¹

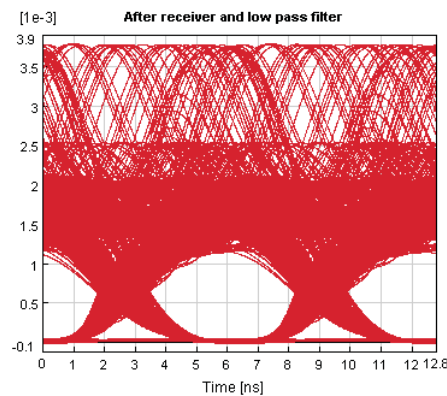


Figure 3: The eye opening of the FSK output data

the eye-diagram shown in figure 3. Although the power fluctuation is substantial, the eye-opening is still clear, which means the signal can be recovered without errors. An additional power penalty will be expected due to the fluctuation of the "one" level. The simulations of the chirp peaks of the payload output of the MZI wavelength converter showed peak-to-peak chirp of 2 to 5 GHz, depending on the input extinction ratio.

Experiments

The wavelength converter under study is an integrated all-active three-port SOA-MZI device. The employed chirp measurement method is based on using a Fabry-Perot filter as a frequency discriminator; see [2] for further details. Measurements of the chirp of the converted signal were performed for operation at 2.5 and 10 Gbit/s.

¹156.25 Mb/s is used in the simulations instead of the 155 Mb/s proposed operation speed, due to computational matters in the simulation software.

We found that the magnitude of the chirp is smaller than 5 GHz peak-to-peak. The sign of the chirp depends on the operation mode of the wavelength converter [3]. In non-inverting operation, the red and blue chirp peaks occur respectively on the rising and falling edges of the output signal. In the case of inverting operation opposite chirp behavior is observed. An example of the result of the chirp measurement is shown in figure 4. The amount of power in the chirp peaks was calculated for different pulse patterns and operating modes. The percentage of the lightwave in the chirp peaks $> |0.5|$ GHz is between 30 – 50% , for $> |1.0|$ GHz between 10 – 30% and for the power of the lightwave in peaks $> |2.0|$ GHz the percentage is between 0 – 8%.

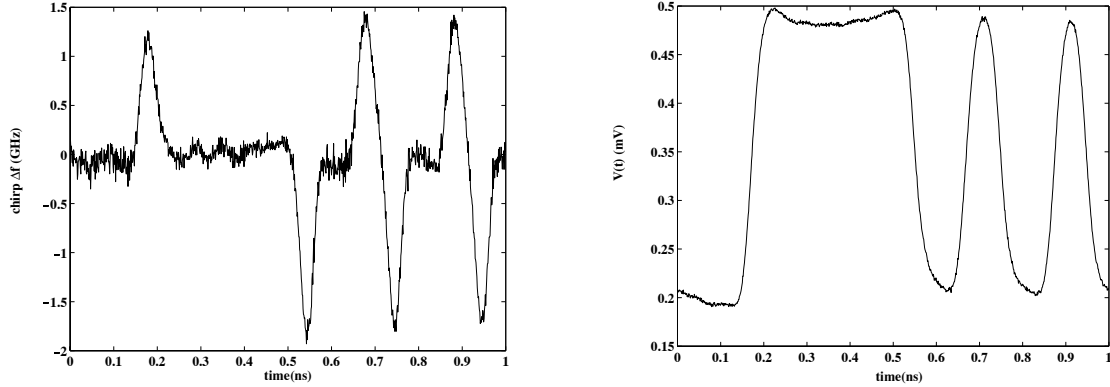


Figure 4: The output pulse, extinction ratio = 13 dB, on the right and the corresponding time-resolved chirp on the left. Co-propagating inverting conversion at a bit rate of 10 Gbit/s. The measured pulse pattern is 1100001010.

Lets consider FSK modulation with frequency deviation of 10-20 GHz, the above chirp values of the converted signal are expected not to impair FSK detection. Apart from the chirp performance, wavelength conversion efficiency and dynamic range are important properties of wavelength converters. The power penalty for wavelength conversion was measured at 2.5 Gbit/s for non-inverting and inverting co-propagating operation mode. A penalty of 1 dB was measured for inverting operation and 1.5 dB for the non-inverting operation at 2.5 Gbit/s. For the counter-propagating operation mode we measured for a non-inverting current setting. The penalty was minimized to 1 dB. The dynamic range for counter-propagation is small compared to the co-propagating operation. The power penalty was also measured for wavelength conversion at 10 Gbit/s. The dynamic range of the wavelength converter is an important parameter to characterize. The data signals may not have the same power level when they reach the AOLS node in a network. The 2-dB dynamic range for 2.5 Gbit/s operation is largest for the non-inverting co-propagating mode. Only co-propagating operation was used for the measurement at 10 Gb/s, because of the limiting bandwidth of the counter propagating mode. The results for non-inverting and inverting operation are respectively 3.9 and 2.6 dB for the 3-dB dynamic range. Inverting operation is still preferable above non-inverting, due to the larger regenerative effect for inverting operation. The result of the dynamic range measurement at 10 Gb/s inverting operation is shown in figure 6.

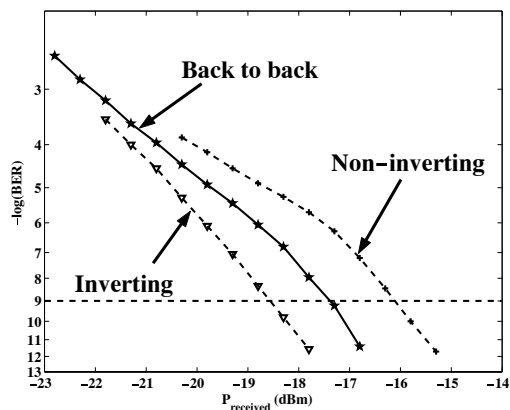


Figure 5: The BER curves for inverting, non-inverting operation and the back-to-back system.

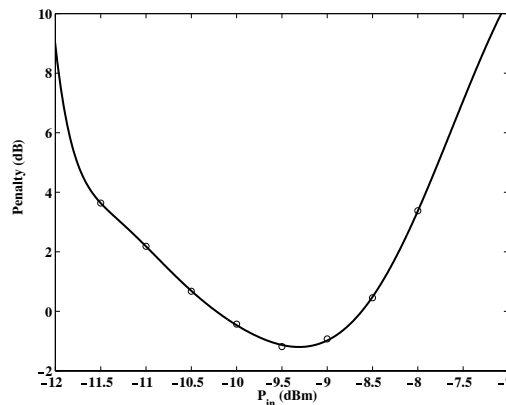


Figure 6: The dynamic range in the inverting co-propagating region at 10 Gbit/s.

Conclusions

The measured chirp peaks of the converted signal are in the order of 5 GHz peak to peak. Considering FSK modulation with frequency deviation in the 10-20 GHz range, the chirp peaks values and their relatively small optical power content are expected not to substantially degrade the FSK receiver performance. It was also observed that the chirp of the converted signal is independent of the chirp of the input signal to the wavelength converter. Chirp measurements using 2.5 Gbit/s direct and external modulation for the input signal showed the same order of magnitude, 5 GHz peak to peak.

Acknowledgement

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References

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