Optical Labelling Transparent to Payload Format Based on Carrier Suppression and Optical Multiplexing

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Abstract *We experimentally demonstrate optical sideband labelling that guarantees the transparency to the payload modulation format for a 10 Gb/s DPSK payload and a 155 Mb/s NRZ label based on carrier suppression and optical multiplexing.*

Introduction

All-optical packet switching using in-band optical label has great potential in future IP-over-WDM networks. The switching and forwarding information is carried as an optical label accompanying the payload data. Labels are received and can be swapped at every node in the core network, while the payload information is transparently forwarded with possible wavelength conversion [1]. Successful transmission, wavelength conversion and labelling swapping have been experimentally demonstrated by using optical sideband label based on the optical carrier suppression for a CW light and optical multiplexing for the payload and label [2-4].

This technique is, however, only applicable to intensity modulated payload because the wavelength of the payload after the wavelength conversion is kept the same as the CW light. As long as a payload is in phase or frequency modulation, e.g., differential phase shift keying (DPSK), some transparent wavelength conversion scheme such as four-wave mixing (FWM) must be considered to preserve the phase information. In this context the wavelength of the converted payload is no longer the same as the CW light but is located at a new wavelength, the sideband label (at the CW wavelength) therefore cannot be employed anymore. We have reported a sideband labelling scheme based on direct suppression of the intensity modulated payload carrier and optical multiplexing [5]. In this paper, we report that this scheme can also be applied for a payload in DPSK modulation. Our experimental demonstration has shown 1.2 dB labelling penalty for a 10 Gb/s DPSK payload and a subcarrier label at 155 Mb/s, clearly validating the transparency of this scheme to the payload modulation format.

Principle

The basic concept of the optical label swapping of the sideband labelled packet is illustrated in Fig.1. The incoming label is separated from the payload by an optical filter and is injected into the label processing module. The pure payload at wavelength f_0 is injected into the wavelength converter with a CW light at f_1. If the wavelength converter is non-transparent, the converted wavelength of the payload is f_1. If a FWM wavelength converter is used in the system, the converted wavelength is $2f_1$-f_0. The converted payload is amplified and split into two parts by a 3 dB coupler. In the first branch the payload carrier is suppressed so that two sidebands are generated. The carrier suppression technique is realized by using two RF signals with π-phase shift to drive a Mach-Zehnder modulator (MZM) biased at its null point [6]. The new label is then modulated onto the sidebands and combined with the payload in the second branch by another 3 dB coupler. In this way the label swapping process is accomplished. Because the sideband signal is generated by the converted payload, it is independent to the wavelength conversion scheme and the payload modulation format, thus achieving the transparency to the payload format.

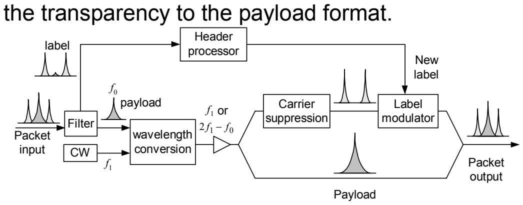

Fig.1. Schematics of optical sideband labelling.

The advantages of this scheme include that the modulation and detection of the payload and label can be achieved independently, the spacing between the payload and the label is fixed thus overcoming the wavelength drift of the lasers. It is worth noting that a limited extinction ratio for the payload has to be used when the payload is in intensity modulation format [5], because the absence of the optical power in payload logical '0' can result in detection failure for the label. However when the payload is in DPSK modulation, the limitation on the ER is totally eliminated due to the constant optical power.

Experimental setup and results

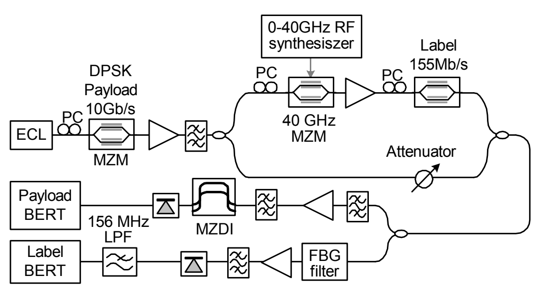

Fig.2. Experimental setup. PC: polarization controller, MZM: Mach-Zehnder modulator, LPF: low-pass filter.

The experimental setup shown in Fig. 2 is used to demonstrate the label insertion process. The signal source is a wavelength tunable external cavity laser (ECL) working at 1550 nm. An MZM biased at its transmission null is used to generate a DPSK signal at 10Gbit/s. The carrier suppression occurs in another MZM (with 40 GHz bandwidth) driven by a sinusoidal clock signal at 30 GHz. By adjusting the polarization state of the polarization controller before the second MZM and the input RF voltage, a suppression ratio of up to 25 dB can be achieved as shown in Fig.3(a). The RF signal results in a spacing of 60 GHz between the two sidebands. The payload and the label separation can be easily achieved because of the relative large spacing. The 155 Mbit/s label is then modulated onto the sidebands. The payload is then combined with the sideband label via a 3 dB coupler, thus the optically labelled packet is obtained.

At the receiver, a fiber Bragg grating (FBG) filter with carefully selected rising edge is employed to extract the sideband label. The DPSK payload is input to a fiber-based well-stabilized Mach-Zehnder delay interferometer (MZDI) to demodulate the DPSK signal. The length difference between the two arms of the MZDI is 2 cm, corresponding to 100 ps delay. The optical spectra of the payload with sideband label, the detected label and the payload are shown in Fig.3. The extracted payload has a signal to noise ratio of about 23 dB. A larger signal to noise ratio can be expected if a bandpass filter is used for the payload and label separation. When deploying a narrow filter in the receiver, the RF frequency for the carrier suppression can be reduced to achieve higher bandwidth efficiency.

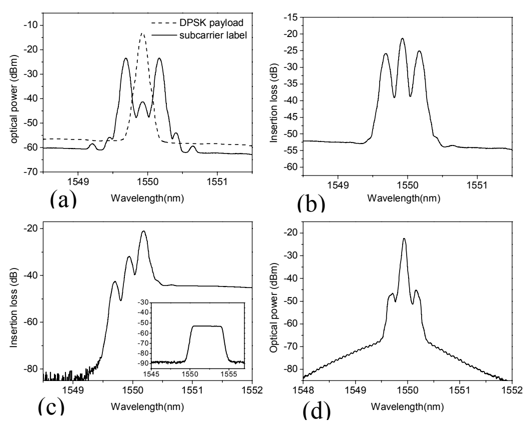

Fig.3. Measured optical spectra for (a) DPSK payload (dash line) and carrier-suppressed label (solid line), (b) payload combined with the label, (c) label after FBG filter, the inset figure shows the reflection spectrum of the FBG, (d) payload after the filter and the MZDI.

The eye diagrams of the original DPSK data is shown in Fig.4 (a). Because the transit between the payload data '1's and '0's will pass through the null of the MZM, the optical amplitude of the DPSK signal is not a constant but with some dips. The demodulated pure DPSK signal and the DPSK payload are shown in Fig.4(b) and (c), respectively. Due to the intrinsic amplitude dips in the DPSK payload and the 60 GHz clock generated by the carrier-suppression process, the received label waveform has a subtle structure (see Fig.4(d)). The micro-structure of the 'mark' bit reveals the information at 10Gbit/s and 60 GHz clock that are superimposed onto the label. Therefore a 156 MHz electrical low-pass filter (LPF) is applied after the photodiode to remove these high frequency interferences. In this way, a clear 155 Mb/s label waveform could be obtained, as shown in Fig. 4(e). The measured BER performance of the payload and label are shown in Fig.4. Error-free detection of both payload and label can be achieved simultaneously. The DPSK payload shows a power penalty of 1.2 dB after optical labelling.

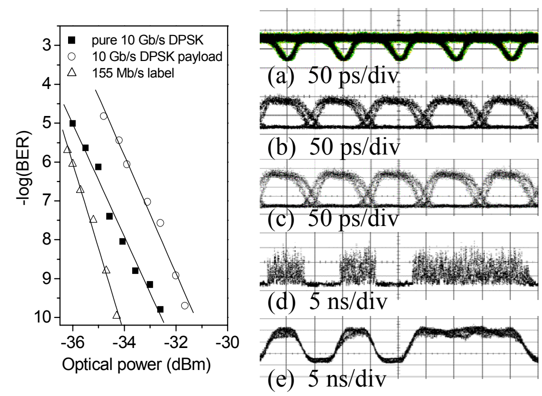

Fig.4. Measured BER curves for the pure DPSK signal and after optical labelling. The detected eye-diagrams and the waveforms for (a) DPSK signal, (b) detected pure DPSK signal, (c) detected payload, (d) detected label before the LPF, (e) label after the LPF.

Conclusions

We have reported a novel scheme of all-optical sub-carrier labelling based on carrier suppression of the payload that can provide transparency to the payload modulation format. We have experimentally demonstrated optical labelling for a 10 Gb/s DPSK payload and 155 Mb/s label with labelling penalty of 1.2 dB.

References

1 D.J. Blumenthal et al, Journal of Lightwave Techn. Vol. 18, 2000, pp. 2058-2075.
2 J. Zhang et al, OFC'03, paper FD5, Vol.2, pp. 653-654, 2003
3 J. Zhang et al, Electron. Lett., Vol.39, 2003, pp. 388-389.
4 J. Yu et al, Photon. Tech. Lett., Vol.16, 2004, pp.320-322.
5 N. Chi et al, Photon. Tech. Lett., Vol.15, 2003, pp. 781-783.
6 R. Montgomery, et al, IEEE Photon. Technol. Lett., Vol.7, No. 4, 1995, pp.434-436.