Integrated electro-absorption modulation DFB laser based all-optical subcarrier label swapping

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Abstract: We propose and demonstrate an all-optical subcarrier label-swapping system incorporating an integrated electro-absorption modulation laser (EML). The experiment results show error-free operation with negative penalty via optical regeneration to the payload.

OCIS codes: (060.2330) Fiber optics communications, (060.4510) Optical communications

1. Introduction

Label swapping is an important technology for providing scalability in optical-label switching (OLS) networks [1]. Recent demonstrations have been limited to using bulky devices such as fiber spools [4] and $LiNbO_3$ MZI modulators [3][5]. The integrated electro-absorption modulation laser (EML) is an attractive device that can provide a very compact, low-cost solution for optical communication systems. This paper proposes and demonstrates an all-optical subcarrier-multiplexing (SCM) label swapping system based on an EML. The experiment shows error-free operation on both the label and the payload after the label swapping. The system is much more compact and simpler than the previous solutions [3-5]. The successful result presented in this paper indicates a step towards realizing a monolithically integrated all-optical label-swapping system on a semiconductor chip.

2. Experiment and Results

Fig. 1 shows the experimental setup for all-optical label swapping. The parallel bit-error-rate tester (ParBERT) synchronously generates the label and the data payload in electrical baseband formats. The bit-rates of the label and the data payload are 155 Mb/s and 2.488 Gb/s. The SCM transmitter generates the optical-label switching (OLS) packets using double-sideband (DSB) SCM with an 11.5 GHz subcarrier. The OLS packet is sent to label extractor 1 where the optical circulator 1 (OC1) and the fiber Bragg grating 1 (FBG1) separate the SCM label and the payload all-optically [2]. FBG1 has a narrow (~ 0.1 nm FWHM) high reflectivity band (> 99.8 %) peaking at the same wavelength (1552.39 nm) as that of the SCM transmitter. Therefore, it reflects the payload signal at the baseband and transmits the SCM label signal. The payload signal goes to the label-rewriting module after being amplified by an EDFA. Another input to the label-rewriting module is the new SCM label, which is obtained by modulating the new label information from the ParBERT onto the 11.5 GHz subcarrier. The dashed-line box at the bottom right of Fig. 1 illustrates the schematic diagram of the optical SCM label rewriting module. The EML is a commercially available integrated electro-absorption modulation DFB laser whose output wavelength is 1555.74 nm. As Fig 2 (a) illustrates, the EML generates two SCM sidebands and an optical carrier in the frequency domain when it is modulated by the new SCM label. The EDFA amplifies the EML's output and sends it to FBG3 through OC3. FBG3 has peak reflectivity at the same wavelength of the EML (1555.74 nm), and it reflects the optical carrier and passes through the two SCM sidebands. Fig. 2(c) and 2(d) show the optical spectra of the reflected and transmitted signals. The reflected optical carrier goes into the Mach-Zehnder interferometer wavelength converter (MZI-WC) as the probe light for the wavelength conversion, while the payload signal obtained by label extractor 1 (as shown in Fig. 2(b)) goes into the MZI-WC as the signal light. Inside the MZI-WC, the cross-phase modulation effect imprints the payload information onto the optical carrier from the EML and wavelength-converts the payload to the wavelength of the new SCM label. Fig. 2(e) shows the optical spectrum of the payload after the wavelength conversion. The polarization beam combiner (PBC) combines the payload and the new SCM label together (as shown in Fig. 2(f)) and finishes the label rewriting operation. The purpose for using two polarization controllers (PCs) and a PBC here is to avoid undesired coherent interference between the two channels [3]. The output of the label-rewriting module goes to the label extractor 2 where the label and the payload are separated again and sent to the detectors. The label extractor 2 has the identical structure as the label extractor 1 except that FBG2's peak reflectivity is centered at the wavelength of EML (1555.74 nm). The label and the payload detectors recover the label and the payload and send them back to ParBERT for bit-error-rate (BER) performance measurements.

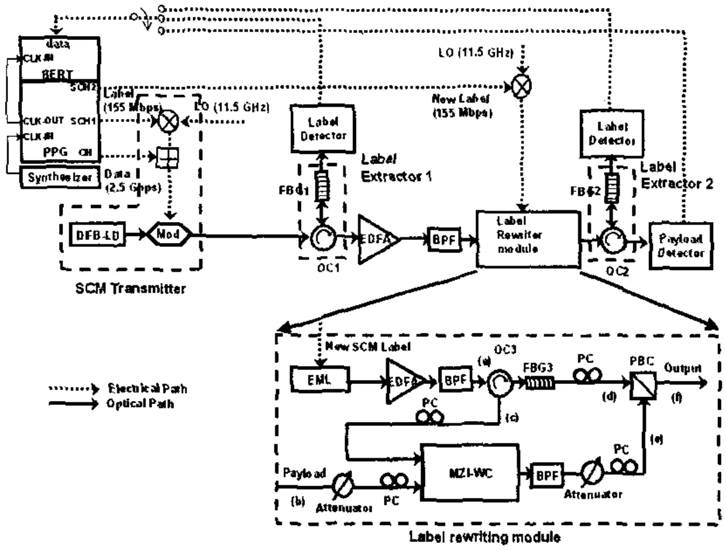

Fig. 1 Schematic diagram of the experimental setup for all-optical SCM label swapping

(PPG: Parallel Pattern Generator; BERT: Bit Error Rate Tester; LO: Local Oscillator; DFB-LD: DFB Laser Diode; Mod: $LiNbO_3$ Optical Modulator; OC: Optical Circulator; FBG: Fiber Bragg Grating; EDFA: Erbium Doped Fiber Amplifier; BPF: Optical Band-pass Filter; EML: Integrated Electro-absorption Modulation Laser; PC: Polarization Controller; MZI-WC: Mach-Zehnder Interferometer Wavelength Converter; PBC: Polarization Beam Combiner)

Fig. 2 shows the optical spectra measured at different points in the label-rewriting module. Fig. 2(a) is the spectrum of the signal from the EML after being amplified. Since the EML is designed for 10 Gb/s operations, its frequency response is weak at 11.5 GHz (~ 15dB attenuation) and this is the primary reason why on the spectrum the optical carrier is much stronger than the two SCM sidebands. Fig. 2(e) shows the final output from the label-rewriting module. The BER performance tests of the label-rewriting module employed 2^{31}-1 pseudo-random bit sequence (PRBS) for both the label and the payload. Fig. 3 shows the BER results for the label and the payload before and after label rewriting. The BER for the label before rewriting is measured at point (d) in Fig. 1 while the BER for the payload before label rewriting is measured at point (b). The BER results for the label and the payload after label rewriting are measured after label extractor 2. The BER measurements prove that the label-rewriting module imposes almost no power penalty for the label. For the payload, there is a 2 dB negative power penalty due to the optical regeneration function of the MZI-WC [6]. The inset eye diagrams also indicate clearer and wider eye openings after the label swapping operation incorporating 2R regeneration. Since the FBGs in this experiment are not ideal (~ 0.1 nm FWHM), the SCM label signal will leak to the baseband signal and cause crosstalk during the separation of the label and the payload. Fortunately, however, this crosstalk can be suppressed effectively by the 2R regeneration of the MZI-WC. Adopting a higher subcarrier frequency will alleviate such crosstalk, but currently the optical-label swapping system is limited by the frequency response of the EML designed for 10 Gb/s operation yielding low modulation (-15 dB) at frequencies that are 10 GHz or higher.

3. Summary

We proposed and demonstrated an all-optical SCM label swapping system employing an integrated EML. The system achieves a zero power penalty for the label and achieves a negative penalty for the payload using optical 2R regeneration in MZI-WC. The majority of the components in this label-swapping system can be semiconductor (*e.g.*, InP), which indicates a step towards possible monolithic or hybrid integration of the all-optical label swapping system in the future.

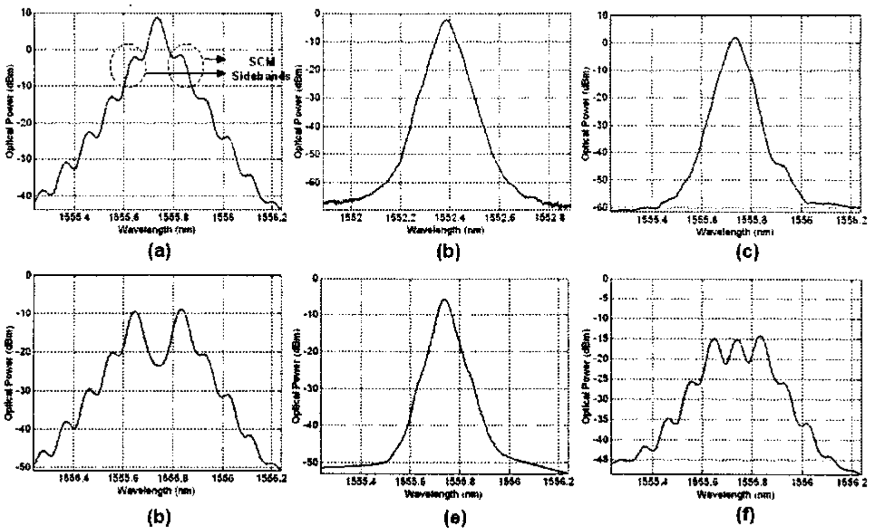

Fig. 2 Optical Spectra of (a) Optical carrier and new SCM label, (b) Data Payload before MZI-WC, (c) Optical carrier reflected by FBG3, (d) New SCM label after FBG3, (e) Data payload after MZI-WC, (f) Label and payload after label-rewriting

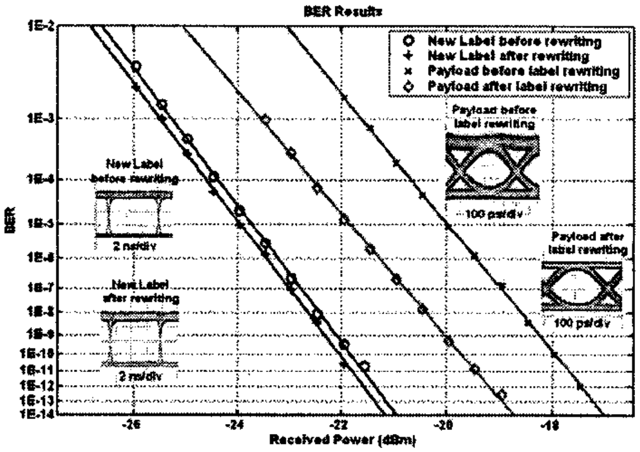

Fig. 3 BER results for label swapping

4. References

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This work was supported in part by the National Science Foundation (NSF) under grant number ANI-998665.