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European Journal of Applied Engineering and Scientific Research, 2014, 3 (4):31-35
(http://scholarsresearchlibrary.com/archive.html)

ISSN: 2278 – 0041
CODEN(USA): EJAEAJ

Performance analysis of MZI in label- swapped networks using integrated soa-based Flip-Flops and Optical Gates

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ABSTRACT

In this letter, we show that all-optical network systems, offering intelligence in the optical layer, can be con- structed by functional integration of integrated all-optical logic gates and flip-flops. In this view, we show 10-Gb/s all-optical 2-bit label address recognized by interconnecting two optical gates that perform XOR operation on incoming optical labels. We also demonstrate 40-Gb/s all-optical wavelength-switching through an optically controlled wavelength converter, consisting of an inte- grated flip-flop prototype device driven by an integrated optical gate. The advantages of these all-optical systems combined with their realization with compact integrated devices, suggest that they are strong parameters for future packet/label switched optical networks.

Key Words: Mach-Zehnder interferometer (MZI), optical flip-flop, optical label swapping (OLS), packet switching, semiconductor optical amplifier (SOA), wavelength conversion, Converter.

INTRODUCTION

NEW generation communication modes such as multiprotocol label swapping [1] have been reported, for solving the mismatch between fiber capacity and router packet forwarding capacity. Optical label swapping (OLS) [2]–[5] has been re- cently reported where intelligent functionalities such as label processing and routing are realized through electronics and advanced integrated devices. Considerable work on OLS labeling has been also reported for coding low-rate labels in different modulation [2] using customized transmitter designs. Up to now, packet routing with lower bit-rate labels has been reported, ranging from megabits per second up to 10-Gb/s labels [3], [4]. In the last few years, research on all-optical signal processing has been fueled through research projects[6]–[8] and the creation of companies offering integrated devices. In order for optical switching to emerge as a viable technological solution, all-optical network systems imple- mentations/designs must be capable of processing high-rate packet traffic with bit-serial labels, thereby yielding increased bandwidth utilization while avoiding customized transmitter configurations. These systems must also be implemented using a single cost-effective photonic integration technology based on monolithic or hybrid integration or combination of both and not customized and costly solutions. In this paper, we analyze two all-optical network systems; a label processor capable of recognizing 10-Gb/s incoming labels and a 40-Gb/s optically controlled wavelength converter, driven by a flip-flop prototype device. These systems can operate at high-speed with low guardband requirements and are

implemented using a single integration technology. Research on integration of multiple gates on a chip [7] suggests that the systems could be integrated on the same chip, avoiding fiber-to-chip coupling and reducing packaging and pigtailing costs.

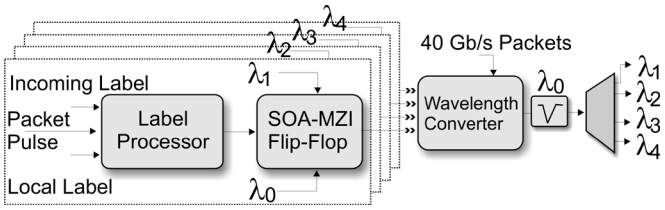

Fig. 1. Concept diagram of all-optical label processing and forwarding.

ALL-OPTICAL ROUTING CONCEPT

Fig. 1 shows the block diagram of the processing core of an all-optical label swapper (AOLS) [6]. The system consists of an array of label processors and optical flip-flops connected to a 40-Gb/s wavelength converter. All-optical label extrac- tion, single pulse extraction, and local label generation using semiconductor optical amplifier Mach–Zehnder interferometer (SOA-MZI) gates is performed as described in [6]. Each label processor compares the incoming label with one permutation and generates a single pulse if a match occurs [6]. Each branch of label processors is connected to an all-optical flip-flop, emitting at two wavelengths, for the case of a 4 4 AOLS node. The common wavelength λ_0 is filtered, al- lowing one of the four wavelengths to propagate depending on which label generates the matching pulse. The flip-flop device is based on two coupled MZI gates, as shown in Fig. 2(a) in order to obtain a very fast switching time. Each gate is pow- ered by one continuous-wave (CW) signal, forming a bistable element with two wavelength states. Toggling between states is achieved by injecting a pulsed signal to one of the two gates to set the device and a delayed version to reset $\{\lambda_0, \lambda_1, \lambda_2, \lambda_3, \lambda_4\}$ vious state. The amount of delay between SET and RESET pulses defines the duration for which the device is in the set state, and for the AOLS domain, it is equal to the packet length. A proto- type device comprising two flip-flops on a single chip was fab- ricated by the Center for Integrated Photonics. Fig. 2(b) shows the silica waveguide motherboard showing the two MZI struc- tures. Fig. 2(c) shows the precision-diced daughterboard with flip-chipped twin SOA devices. Packet routing is achieved by connecting the output of the flip-flop to an SOA-MZI wave- length converter. Depending on which label processor generates a matching pulse, the appropriate flip-flop is set, emitting at one of the four wavelengths to which the payload will be converted, as shown in Fig. 1.

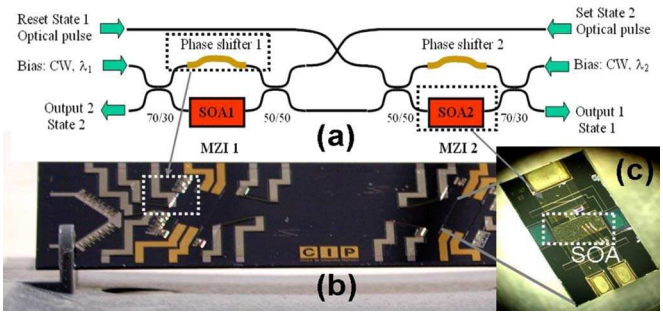

Fig. 2. Developed flip-flop using hybrid technology: (a) schematic of device,
(b) planar silica motherboard, (c) daughterboard with twin SOAs flip chipped and wirebonded.

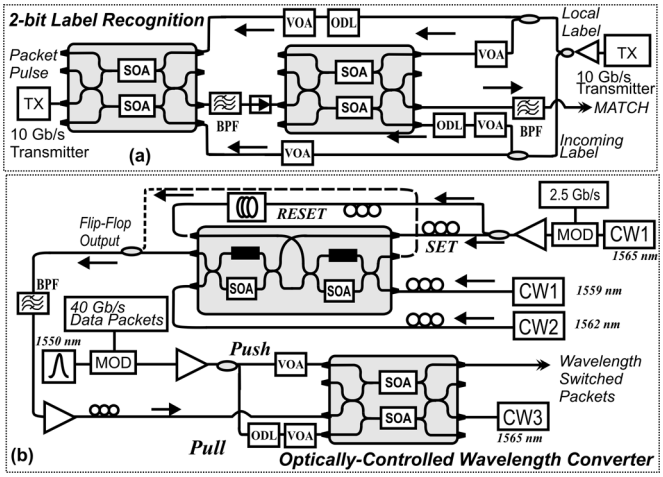

Fig. 3. Experimental setups of the all-optical network systems, (a) all-op- tical label processor and (b) optically controlled wavelength converter.

IMPLEMENTATION OF SYSTEMS

Fig. 3 shows the two experimental setups that were used to demonstrate each system individually. Fig. 3(a) shows the experimental setup of the label processor. A suitable transmitter was implemented, generating the label patterns and the clock signal used as input to the optical gates. A pulse-generating laser was used as the clock source, whereas the labels and control signal were modulated using high-speed pattern generators. The

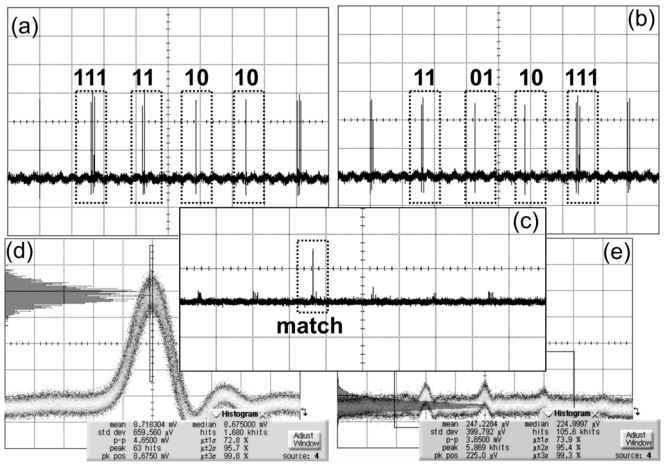

Fig. 4. Experimental results of label processor (a) incoming labels, (b) local labels, (c) match pulse, and (d), (e) show corresponding "1" and "0" levels.

label processor consists of two cascaded SOA-MZI optical gates configured to perform XOR operation on the incoming and local labels. A matching pulse appears at the output of the system only if a complete match occurs. Polarization control was only necessary at the input of each gate, since the SOAs used had low polarization dependence. The optical delay lines were used to fine-tune the synchronization between interacting signals within the optical gates and the variable optical attenuators were used to adjust each signal power for optimized switching within the SOAs.

Fig. 3(b) shows the experimental setup for the tunable wave- length converter used to demonstrate the concept of all-optical routing. Two CW optical sources emitting at 1550 and 1570 nm were used for providing the two states to the optical flip-flop prototype. A pulsed signal was also generated by modulating a CW laser emitting at 1560 nm that acted as the control pulse pro- viding the SET and RESET signals. The signal had a pulsewidth of 500 ps and a period of 15 ns. The flip-flop output was con- nected to the wavelength converter, realized using an SOA-MZI gate operated in push–pull mode. A counter propagating holding beam was also used for removing transients within the

SOAs and reshaping the generated CW signal from the flip-flop. Finally, a 40-Gb/s pattern generator was used to modulate data on short pulses provided by a pulse generating laser. Depending on the measurement required, the pattern generator was programmed to produce continuous or packet-mode 40-Gb/s data.

RESULTS

Fig. 4 shows typical experimental results of the 10-Gb/s label processor. Fig. 4(a) and (b) shows 2-bit label combinations to be compared. Each label is spaced 3.0 ns, whereas the "111" combination was included for assisting the synchronization of signals during the experiment. The local and incoming labels were synchronized so as "01" coincides with "10" giving a com- plete match. The generated matching pulse at the output of the label processor is shown in Fig. 4(c) verifying the operation of the subsystem. Fig. 4(d) and (e) shows the eye diagrams of "1" and "0" levels, revealing an extinction ratio of 10 dB. Figs. 5 and 6 show experimental results of the 40-Gb/s optically con- trolled wavelength converter. In order to assess the quality of the CW signal provided by the flip-flop, static bit-error-rates

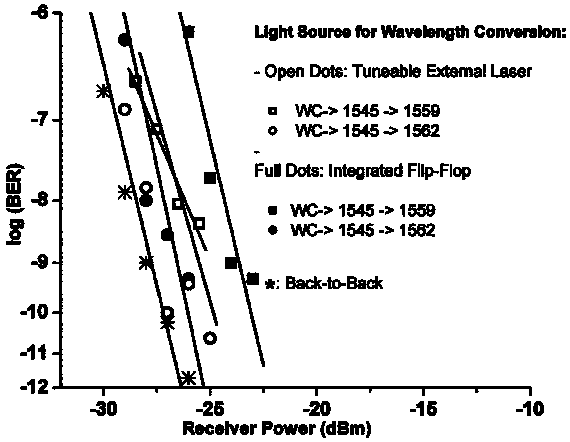

Fig. 5. BER measurements for static flip-flop operation.

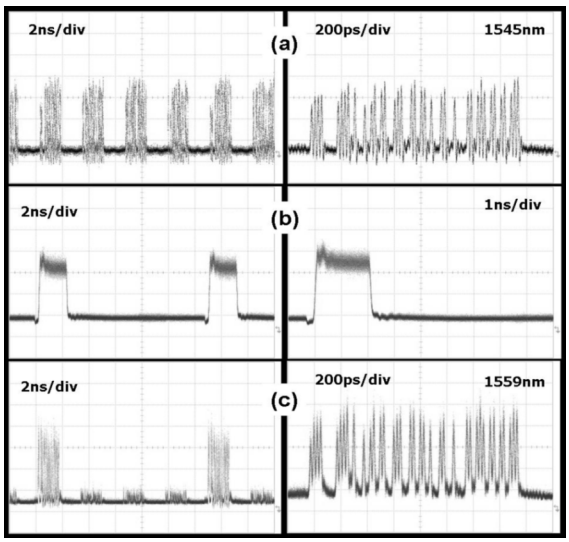

Fig. 6. Eye patterns showing all-optical routing. (a) Incoming packets, (b) flip-flop output, (c) wavelength-switched packets.

(BERs) were measured using continuous 40-Gb/s data. Specif- ically, the flip-flop state was controlled so as either the 1550 or 1570 nm was the dominant state. Fig. 5 shows the BER mea- surements for back-to-back and

wavelength conversion using CW light from a tunable laser source and from CW light pro- vided by the flip-flop. The power penalty was measured to be less than 1.8 dB when wavelength converting from the tunable source and the flip-flop prototype for both wavelengths. There was a polarization drift between the transmitter and the optical subsystems due to the implementation using long fibers and bulk fiber-pigtailed components, which gave a small fluctuation during the BER measurements. The polarization drift affected the input signals to the flip-flop and the wavelength converter, due to the polarization dependence of the silica motherboard. Higher stability can be obtained by minimizing the length of the fiber interconnections between the active and passive com- ponents or the implementation of the subsystems on a single chip [11]. The flip-flop was operated using the pulsed signal to achieve dynamic switching between states. The RESET pulse was delayed 2.5 ns with respect to the SET pulse, corresponding to the duration of a single packet. Data packets were produced by programming the 40-Gb/s pattern generator to produce 1.9-ns packets separated by 3.2 ns. Fig. 6 shows oscilloscope traces.

Fig. 6(a) shows the incoming packets, and Fig. 6(b) shows the CW generated from the optical flip-flop, when triggered by the SET and RESET pulses. Fig. 6(c) shows the corresponding wave- length-converted packets. The flip-flop exhibited an extinction ratio of 9.5 dB, which was the main reason of crosstalk from re- maining packets. The SOAs were driven with 160 and 350 mA in the flip-flop and the wavelength converter, respectively. The SET/RESET optical signals were found to be polarization-independent and no significant signal-to-noise ratio degradation was observed at the output of the system. The reduced extinction ratio of the flip-flop can be enhanced by using a 2R regenerator at the processor/node output in order to allow for new data packets to be inserted. Higher extinction ratio greater than 20 dB can also be achieved by optimizing the current device design or utilizing a different flip-flop configuration [10]. In the case where more label bits are required, a feedback-based XOR correlator can be used [9]. The flip-flop prototype has two independent MZI optical flip-flops for generating four different wave- lengths. Hence, a single device is sufficient for a 4x4 core node.

CONCLUSION

We have demonstrated that all-optical network Systems can be built by functional interconnection of SOA-MZI based integrated devices. Successful label recognition and optically controlled wavelength conversion of short optical packets was shown with fast-switching prototypes.

REFERENCES

[1]A. Viswanathan, N. Feldman, Z. Wang, and R. Callon, *IEEE Commun. Mag.*, vol. 36, no. 5, pp. 165–173, May **1998**.
[2]K. G. Vlachos, I. T. Monroy, A. M. J. Koonen, C. Peucheret, and P. Jeppesen, *IEEE Commun. Mag.*, vol. 41, no. 11, pp. 43–49, Nov. **2003**.
[3]J. Hu *et al.*, "Error-free multi-hop cascaded operation of optical label switching routers with all-optical label swapping," presented at the OFC **2003**, Anaheim, CA, Paper FS1.
[4]D. Wofson *et al.*, "All-optical asynchronous variable-length optically labeled 40 Gbps packet switch," presented at the ECOC **2005**, Glasgow, Scotland, Postdeadline paper Th4.5.1.
[5]V. Lal *et al.*, "Monolithic widely tunable optical packet forwarding chip in InP for all-optical label switching with 40 Gbps payloads and 10 Gbps labels," in *Proc. ECOC* **2005**, Glasgow, Scotland, vol. 6, pp. 25–26.
[6]F. Ramos, E. Kehayas, J. M. Martinez, R. Clavero, J. Marti, L. Stam- poulidis, D. Tsiokos, H. Avramopoulos, J. Zhang, P. V. Holm-Nielsen, N. Chi, P. Jeppesen, N. Yan, I. T. Monroy, A. M. J. Koonen, M. T. Hill, Y. Liu, H. J. S. Dorren, R. Van Caenegem, D. Colle, M. Pickavet, and B. Riposati, *J. Lightw. Technol.*, vol. 23, no. 10, pp. 2993–3011, Oct. **2005**.
[7]G. Theophilopoulos, "All optical signal processing: A glance into the future," presented at the Workshop on All-Optical Wavelength Conver- sion and Signal Processing for Next Generation Networks (OFC **2005**), Invited Talk.
[8]D. J. Blumenthal and M. Masanovic, "LASOR (Label Switched Op- tical Router): Architecture and underlying integration technologies," presented at the ECOC **2005**, Glasgow, Scotland, Paper We2.1.1.
[9]J. M. Martinez *et al.*, "," presented at the ECOC **2002**, Copenhagen, Denmark, 2002, Paper P.4-08.
[10]Y. Liu *et al.*, "All-optical switching of 80 Gb/s data packets using a wavelength converter controlled by a monolithically integrated optical flip-flop," presented at the ECOC **2005**, Glasgow, Scotland, Postdead- line paper Th. 4.3.2.
[11]P. Bernasconi, L. Zhang, W. Yang, N. Sauer, L. L. Buhl, J. H. Sinsky, I. Kang, S. Chandrasekhar, and D. T. Neilson, *J. Lightw. Technol.*, vol. 24, no. 1, pp. 71–75, Jan. **2006**.S