Demonstration of an All-Optical Data Vortex Switch node base on MZI-SOA gates

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We have proposed and demonstrated the fully all-optical operation of a data vortex switch node based on MZI-SOA gates. All-optical self-routing of WDM 10Gbps optical packets has been successfully achieved.

Introduction

The current and forecast increase in the Internet traffic and the growth of new and diverse kind of services are calling for higher data rates and flexibility that current network cannot offer. Optical packet switching has emerged as a solution for these demands by means of increasing the throughput, efficiency, transparency and flexibility. In order to meet these promising expectations, it is required to perform the routing and switching operations in the optical domain. At the current level of development of photonic technology, hybrid optical-to-electronic configurations are used to process the label information due to the immaturity of optical techniques to perform those operations. Moreover, operations easily performed electronically such as packet buffering and intelligent control are still challenging to be realized all-optical and solution need to be searched in order to realize the so longed all-optical packet switching.

A new packet routing architecture called the Data Vortex[1] was proposed that is uniquely free of an optical buffer and enables a simple routing strategy for large scale low latency packet switch fabrics. So far, several researches[2,3] have reported operation of Data Vortex switch structures. In their approaches, an electrical decision circuit for performing the routing decision was employed. However, electrical signal processing may introduce performance loss and latency, especially at higher data rates.

In this paper, we have proposed and demonstrated a fully all-optical operation of a data vortex switch node. All-optical self-routing decision are obtained by an optical AND logic operation between a routing and an optical control signal. WDM 10Gbps packet routing through the proposed node structure has been successfully achieved.

Proposed Data Vortex node structure

The proposed all-optical Data Vortex node (Fig. 1) consists of two Mach-Zehnder Interferometers with SOA (MZI-SOA). The upper and lower MZI-SOA act as an optical AND gate and an optical switch respectively. A WDM-encoding technique for the optical packets payload and headers[2] was used, which increases the network capacity. In addition, encoding the header bits by WDM substantially simplifies the routing strategy at the node. As each cylinder in a Data Vortex switch decodes a specific header bit in a binary tree fashion, passive wavelength filtering can be implemented in the nodes to perform the routing operations.

If a WDM-header encoded optical packet comes into the switch node, a small portion of header signal is extracted by the optical band pass filter with a particular wavelength which is uniquely dedicated to a particular cylinder. The extracted header signal interacts with the control signal from an inner cylinder node at the upper MZI-SOA. The output signal of this upper MZI-SOA controls the switching function of the lower MZI-SOA gate. The output signal of the upper MZI-SOA is only ‘on’ when both control and routing signals are of ‘1’-state, resulting in routing of the packet to the inner cylinder. This self-routing decision is an *AND* logical operation successfully performed by the upper MZI-SOA gate. In the case of the output of the upper MZI-OSA being ‘off’, the input optical packet passes to the same cylinder.

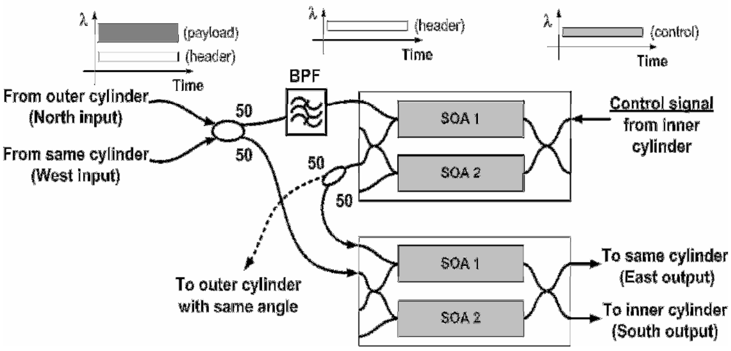

Fig. 1 Configuration of the proposed all-optical Data Vortex node employing MZI-SOA gates

Experiment setup

Fig. 2 shows the experimental setup. The setup consists of two parts: the optical packet generator and the Data Vortex switch node. The optical packet comprised two payload signals (10G, optical clock(1552.52nm) and LD1(1557.36nm)) and a header signal (LD2(1554.13nm)). Electrical data of payload and header bits was generated by a pulse pattern generator (PPG1). The packet length was 16ns, including 2.4 ns guard time as shown in fig. 4. In the experiment, the payload and header had contained the same data by using the same intensity modulator to simplify the time aligning between the payload and header signals. The control signal was generated by the PPG2 and delayed to align it with the extracted header signal at the upper MZI-SOA.

To emulate packets propagating across multiple node hops, a re-circulating configuration was used. For this purpose, the signal from (S)outh output was connected to the (N)orth input with two time slot delay: see Fig. 2. A fiber bragg grating (FBG) was employed to eliminate the control signal from (S) due to the co-propagation configuration used in the lower MZI-SOA. The packet routing was observed at (E)ast deflection output port.

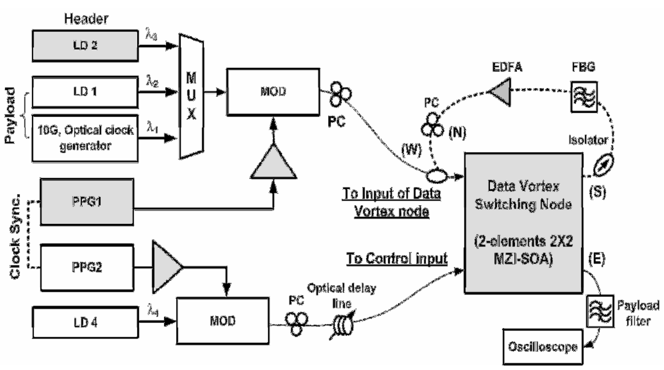

Fig. 2 Experiment setup. The black box of Data Vortex switching node has the architecture in Fig. 1

Experiment results

To verify the successful routing function, we examined the signal trace at each input and output port. The inset (1) of fig. 4 shows the initial input sequence. We programmed an initial pattern sequence ”001100 100011 001100 110011 000000 000000” and this same pattern was repeated continuously. Among these bits, the last twelve ’0’ bits were inserted to distinguish a given sequence from the following one.
A portion of the input packet signal power was tapped and sent to the first MZI-SOA to perform the AND logic decision logic operation. Out of this input packet, the header signal was extracted (filtered) and AND gated with the input control signal as shown in the inset (2) of fig. 4. The only ’on’ bits at the output of the upper MZI-SOA are those when both the header and control bit were simultaneously ’1’. The input packet is routed either to the same or inner cylinder node in accordance with these control output bits. The routing result is shown in the insets of (4), (5) of fig. 4. The bits shown in the inset (5) are the result of routing to the (S) port at the lower MZI-SOA and were used as the re-circulation input signal. The bits shown in the inset (4) are the deflected ones to port (E). The spike signal shown in the inset (4), after four bits are due to the mis-alignment between the control output from the first MZI-SOA and the input packet signal.
The (S)outh output signal (inset (5)) was connected to the (N)orth input and the result are shown in the inset (6) of fig. 4. The signal after recirculation is observed somewhat noisy due to the sub-optimal input optical power level to the MZI-SOA (after recirculation) and added ASE noise. This situation causes the variation of switching condition of MZI-SOA as the power level of the probe and pump signal is changed. Consequently, each bit showed somewhat different switching performance. Nevertheless, the routing of both of the single and re-circulation path was successfully achieved and its performance can be improved by further optimization of operation conditions.

Conclusions

In this paper, we have proposed and demonstrated a fully all-optical data vortex switch node. All-optical self-routing decision are performed as a AND logic operation in a MZI-SOA switch between an optical routing and control signal. The output of this AND operation controls, all-optically, a second of MZI-SOA completing in this way all-optical packet routing. Successful experimental demonstration of WDM 10 Gb/s packet routing through the proposed structure has been achieved.

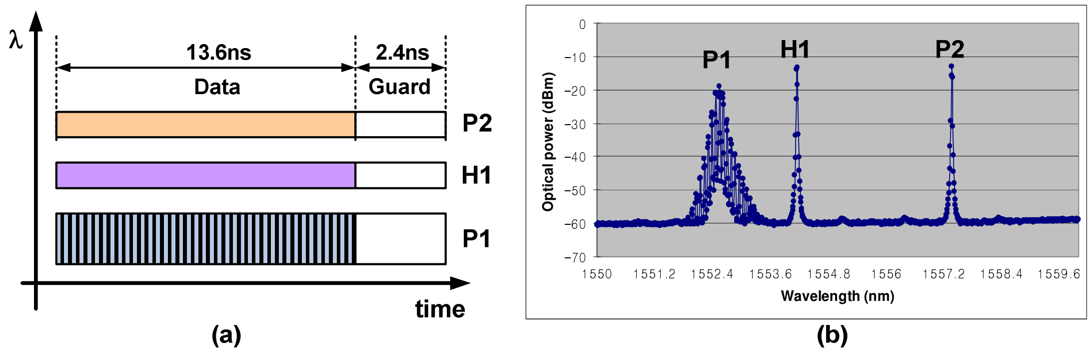

Fig. 3 Structure of the optical packet (P1: first payload (1552.52nm), P2: second payload (1557.36nm), H1: header (1554.13nm))

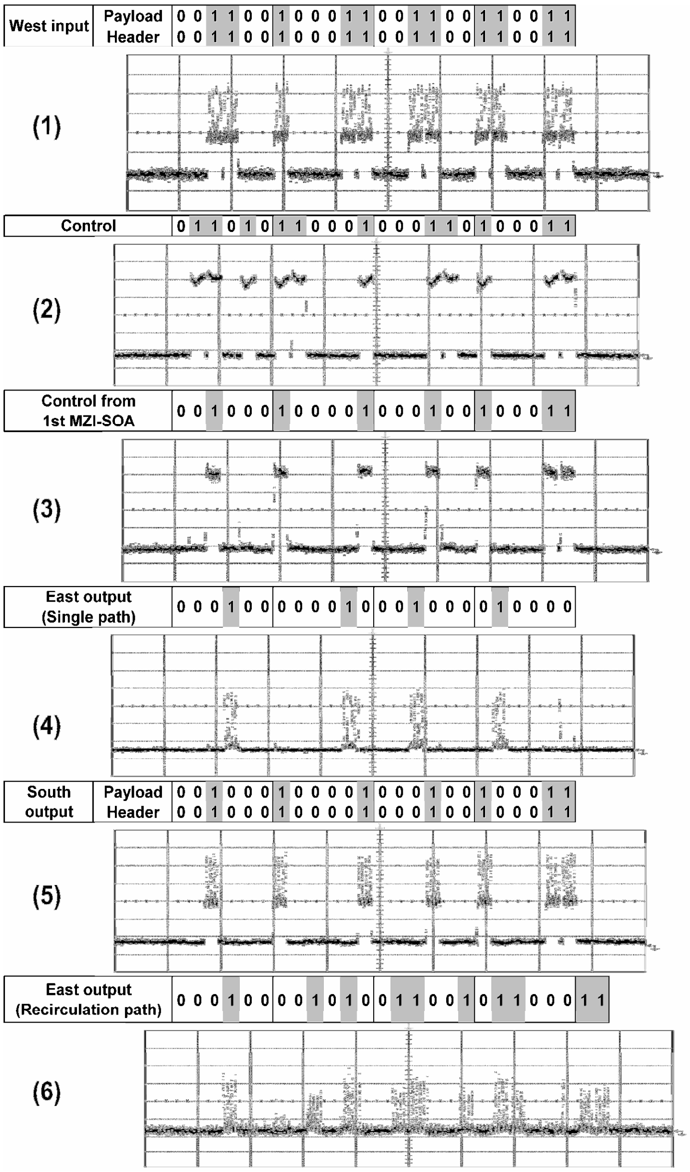

Fig. 4 Signal traces at each input and output port

Acknowledgements

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References

[1] C. Reed, "Multiple level minimum logic network", U.S. Patent 5996020, Nov. 30. 1999.

[2] Qimin Yang et al., "WDM Packet Routing for High-Capacity Data Networks," J. Lightwave Technology, vol. 19, pp. 1420, 2001.

[3] Qimin Yang et al., "Traffic Control and WDM Routing in the Data Vortex Packet Switch," IEEE Photon. Technol. Lett., vol. 14, pp. 236, 2002.