

An ultra fast optical header replacement technology and its application for broadband optical packet switch

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Abstract: An optical header replacement technology based on Self Electro-optic Effect Devices (SEEDs) is presented. By using the measurement result of a 75 μm long SEED device, we simulate an 8 Gbps throughput is achievable. Based on the switching characteristics of SEEDs, we proposed several methods to improve the SEEDs switching speed. An ultra fast switching speed at 50 Gbps is achievable by integrating external components and applying a pair of preset pulses. Due to the convenience of operation in both the optical domain and the electrical domain, it is very suitable for optical header processing; therefore it is an ideal candidate solution for optical fast packet switch.

Introduction

In paper [1], an all-optical shift register was presented; this shift register can be operated in the electrical domain as well as in the optical domain. It is very suitable for optical header replacement, and ideally can be used in optical packet switching. Unfortunately, since the implementation was based on a 326 μm long device, the device capacitance limited the switching speed.

In this paper, several improvements are applied to the device both internally and externally. By using a short device (75 μm long), the switching speed can be up to 50 Gbit/s. Considering the advantage of this device and the character of MPLS switching, an all-optical MPLS switch based in SEEDs is presented.

Improvement of SEEDs

The detail of the device physics can be found in [2]. SEED's photo current-voltage characteristics for different waveguide lengths are shown in Figure 1. The input laser power is -6 dBm at 1520 nm; considering coupling losses of the waveguide, the estimation of the input power into the device of -12 dBm is reasonable. A region of negative differential resistance was observed. The size of the device should be optimized, if the size is too large, the device capacitance becomes larger, as a consequence, the switching speed is lower. On the other hand, if the device is too small, the absorption of photons will be more inefficient.

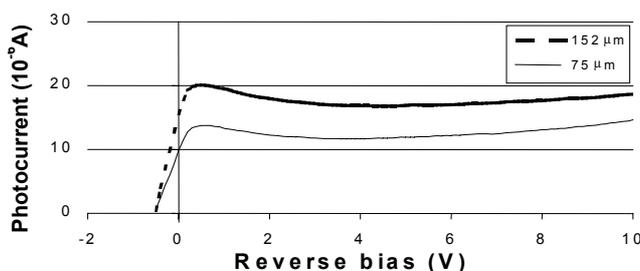


Figure 1 Photo current-voltage characteristic for different waveguide lengths

There are several ways to improve the switching speed of the S-SEEDs: 1) By adding more quantum well layers and reducing the length of the device, the device capacitance will be decreased, however the photo current can stay at the same level, therefore the switching speed can be faster.

With the device 75 μm long, the switching simulation was performed by applying an input data pulse of peak value of 1mW and initial value of 0.1 mW, the referencing input power is keeping at 0.55 mW constantly; the wavelength is 1520 nm; the switching of S-SEEDs is shown in Figure 2. The switching time can be as short as 0.125 ns, which means the S-SEEDs can be operated at a speed of 8 Gbps.

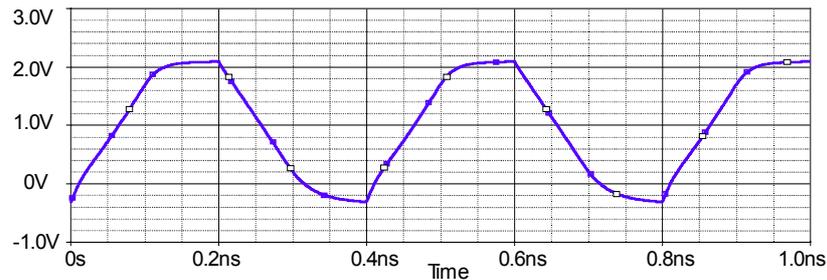


Figure 2 Switching voltage of S-SEEDs, the input peak value of 1mW, the wavelength is 1520 nm

2) By integrating with external components as shown in Figure 3. A pair of inductors compensates the S-SEEDs capacitance.

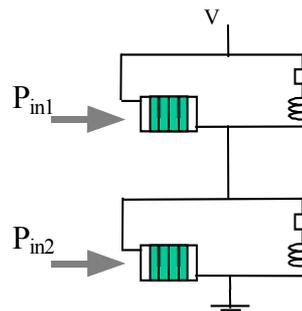


Figure 3 Improvement of SEED by using external integrated components

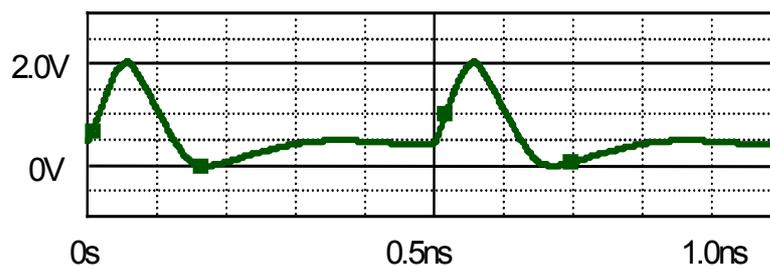


Figure 4 Switching voltage of S-SEEDs with external resistor (12 kΩ) and inductor (1 μH)

From Figure 4, we can see by using a integrated inductor, the device switching speed can be up to 10 Gbit/s

3) By using a pair of preset pulses before the optical data is injected into the device.

This operation uses a state-preset pulse operating at wavelength several nanometers longer than the SEEDs working wavelength. When the working wavelength is increased, the current peak will shift to a higher voltage [2]. At the longer wavelength, the I-V curves tilt inward as shown in Figure 5 resulting in a single point of intersection.

If the preset pulses are equally applied to the SEEDs windows, the SEEDs will be set at the unstable state until the preset pulses are removed. After that any difference between data pulses P_{in1} and P_{in2} will unambiguously determine the state of the S-SEEDs. This operation reinitializes the device before data inputs set the state of S-SEED, while allowing the clock and input signal to operate at the desired wavelength. The order of operation is: state-preset pulse initializes the S-SEEDs at the unstable point; then P_{in1} and P_{in2} work together to switch the S-SEEDs; after that clock pulses read out the S-SEEDs states with certain optical gain. The switching timing is showed in Figure 6.

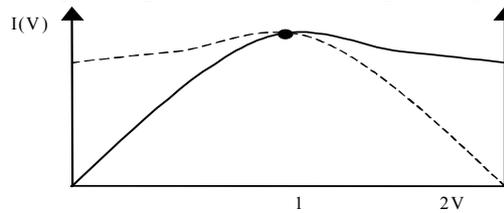


Figure 5 I-V Switching characters of S-SEEDs at a longer wavelength

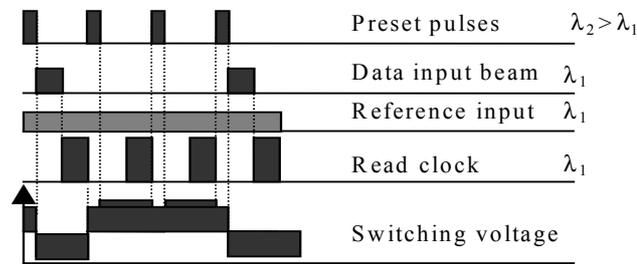


Figure 6 Switching timing of S-SEEDs with set-preset beams

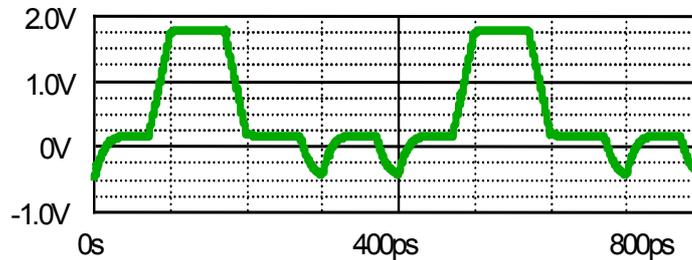


Figure 7 Switching voltage of S-SEEDs with external 800 μ W preset pulses

The switching time can be shortened to 30 ps as follows from Figure 7, which means the speed of 33 Gbit/s is achievable.

3) If we combine the two methods, even better improvement can be seen in Figure 8, the switching speed can be up to 50 Gbit/s.

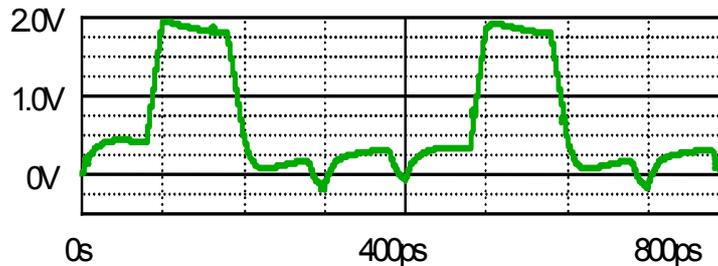


Figure 8 Switching voltage of S-SEEDs with external resistors (12 k Ω), inductors (1 μ H) and external minimum 600 μ W preset pulses

The application of the optical shift register

In Figure 9, an all-optical MPLS switch based on SEEDs shift register is presented. An all-optical shift register constructed by using an S-SEEDs array is used to process MPLS labels and shift the IP packets. Optical connections (i.e. passive optical waveguides) are integrated between two neighbouring memory cells. The clock signals of CLK and $\overline{\text{CLK}}$ can be generated by current modulating two laser diodes. After the two clock signals are coupled into the chip, they can be splitted by integrated beam splitters into CLK and $\overline{\text{CLK}}$ signals, which are connected to the odd memory cells and even memory cells respectively. “Data in” and “Ref” signals can be coupled into the first S-SEEDs optical windows by applying a coupling system; the optical clock signals are coupled to the SEEDs windows by effective waveguide couplers. A electrical switch controller provides the clock synchronization, interface, label swapping, and network layer routing function by reading for LSRs (Label Switching Routers) and LERs (Label Edge Routers) and writing the all-optical shift register for LERs.

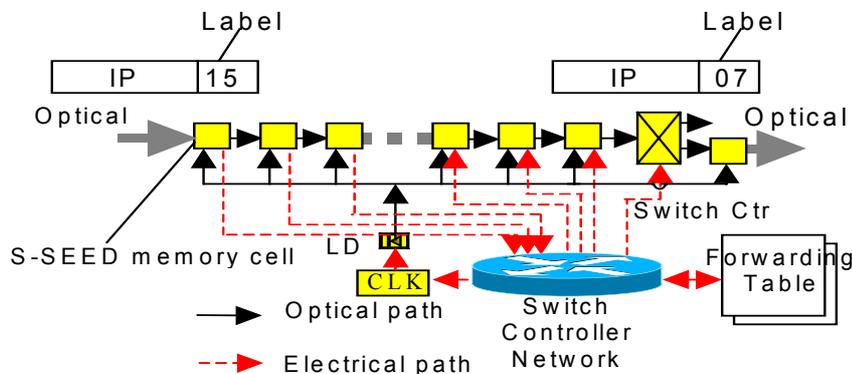


Figure 9 The implementation of all-optical MPLS switch based on SEEDs

Conclusion

In this paper, we proposed three methods to improve the switching speed of an all-optical shift register based on SEEDs, which can be used to implement an all-optical MPLS switch, optical wavelength convertor, optical modulator and optical memory. With combination of two improvements, the achievable speed of 50 Gbps throughput is competitive for ultra fast optical communication systems.

Acknowledgement

This work is part of the project “All-optical ATM switch based on SEEDs”. This project is supported by the Dutch Technology Foundation (STW).

References

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