Path Divertibility in a Spatial- and Wavelength-Selective Switching Fabric

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Abstract: We demonstrate a path diversion algorithm in a 4x4x4λ spatial- and wavelength-selective switch fabric. Experiments show successful rerouting of modulated signals upto 16 Gbps with error-free (BER$<10^{-12}$) paths established non-interruptively.

1. Introduction

Bandwidth bottlenecks in high-performance computing systems and data center networks highlight the growing demand for high-bandwidth and reconfigurable optical interconnects. Silicon photonic spatial-and-wavelength selective switches (SWSS) offer a scalable, high-throughput, and adaptive solution by using ring resonators to select and steer modulated wavelengths to arbitrary outputs [1].

To maintain maximum throughput and flexibly accommodate myriad workloads, non-interrupted reconfigurability of the network is essential. The classic "make before break" (MBB) network rerouting strategy has been used for optically-switched topologies [2] and was successfully demonstrated in low/zero-error rerouting for wavelength-selective switches. However, there are diminishing returns for good utilization when the workload is skewed, i.e. there are hotspots of high-demand wavelengths [3,4]. Here, we have demonstrated for the first time, non-interruptive signal path diversion on a 4x4x4λ SWSS, showing error-free (BER$<10^{-12}$) signals before and after reroute for a 16 Gbps signal.

2. Path Diversion Algorithm Design

In our algorithm, signals are rerouted to resolve routing conflicts via an MBB operation, with switching elements reallocated by path-doubling and power gating. Figure 1(b) shows a node in the SWSS fabric, featuring two cascaded wavelength-selective microring resonator (MRR) devices that are placed adjacent to orthogonal buses intersecting at a waveguide crossing. A termination connected to the "dead-end" of each MRR's drop bus helps eliminate optical reflections. The first stage of the path diversion algorithm involves forming an alternate route, Route 2 (Figure 1(c)), by tuning the two pairs of rings at which the signal would turn in the fabric to resonate at this wavelength, for the desired path doubling. Route 1 is then broken gradually to minimize interruptions or errors seen in this signal at the output: one ring is detuned by 3dB, then a ring from the other pair is detuned by $\sim$2dB, then all four rings are power-gated at the response rate of the control module interface to Python. The duration of each of these stages were later lengthened, as seen in 2(d), to allow for a statistically significant number of samples to be collected by our equipment, demonstrating error-free signaling before and after dynamic rerouting.

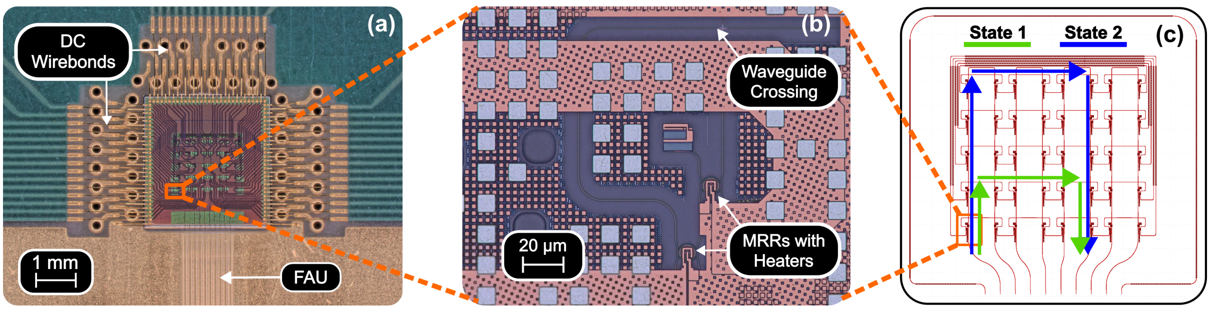

Fig. 1: (a) Micrograph image of the wirebonded and optically packaged 4x4x4λ switch circuit. (b) Micrograph of a single switching element comprised of two cascaded microring resonator (MRR) devices and a silicon waveguide crossing. (c) Architectural layout view of the two switch states traversed in this divertibility experiment.

3. Implementation and Results

The 4x4x4λ switch photonic integrated circuit (PIC), shown in Figure 1(a), was fabricated through AIM Photonics and DC-wirebonded onto a custom PCB with a fiber attach unit (FAU) at Optelligent. Figure 1(b) shows the unit switching element, made entirely with standard AIM Process Design Kit components. The electrical fanout of the switching element heaters supports complete control of the switch state, as depicted in Figure 1(c).

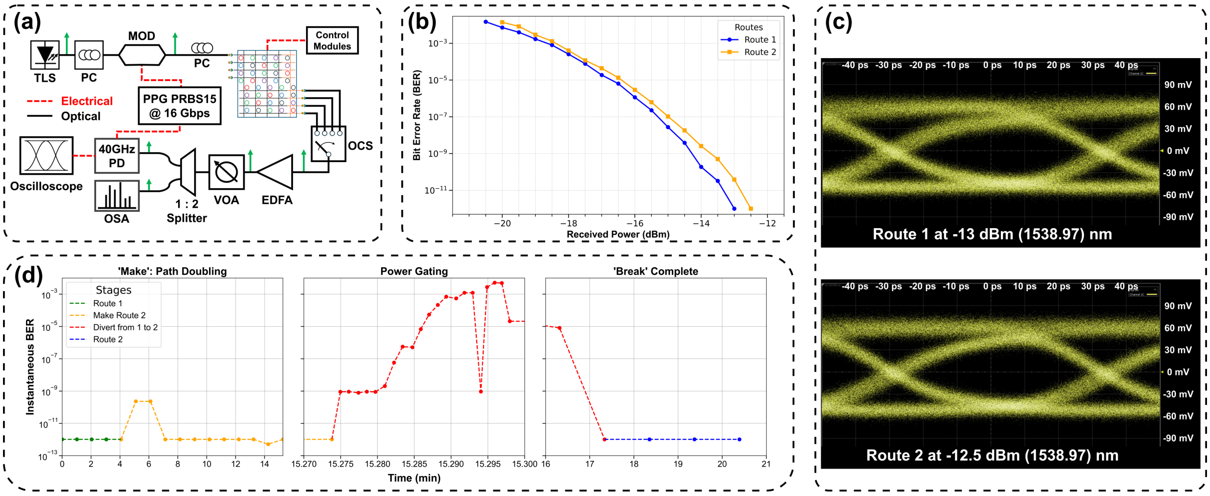

Fig. 2: (a) Schematic of the experimental setup. (b) BER curves of the PRBS15 transmitted data received by a commercial receiver at 16 Gbps. (c) Open-eye diagrams received through each route through the switch. (d) Instantaneous BER curve computed from the accumulated error count for a complete diversion cycle.

With the experimental setup in Figure 2(a), switch operation was characterized by transmitting a modulated optical signal at 16 Gbps, to record both eye diagrams and Bit Error Rate (BER) (Figures 2(b) and (c)). Optical measurements while thermally tuning the MRRs indicate a thermal time constant of 12μs for an estimated switch speed of 80 kHz. During diversion, the accumulated error count from the BER tester (Anritsu MP1900A) can be sampled live. This instantaneous BER measurement trace (Figure 2(d)), post-processed in Python to account for the finer sampling window during diversion, demonstrates a switching completion time of $\sim$1.5 seconds - limited only by the $\sim$70ms response latency of our control module interface to Python. The final Route 2 BER measurement at the end of diversion shows similar performance to route 1 before diversion, indicating strong reliability and reconfigurability. Repeated experiments for various paths and input-output pairs across the fabric ensured algorithm reproducibility.

4. Conclusion

We have experimentally shown path divertibility for modulated signals up to 16 Gbps. Our rerouting algorithm establishes error-free (BER$< 10^{-12}$) paths non-interruptively, limited only by the control module interface and ostensibly as fast as the switching elements' time constant of $\sim$12μs. By path-doubling and power-gating to reallocate switching elements, we demonstrate high utilization of a 4x4x4λ SWSS fabric. Our experiments have been reproduced for various paths and input-output pairs across the fabric.

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