Dilated 2x2 Hybrid MZI-SOA Switch Circuit Routing 100Gb/s DWDM Data

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Abstract: This paper presents a dilated 2×2 hybrid MZI-SOA switch circuit routing 10 wavelengths of 10Gb/s/channel DWDM data. MZI switches using a dilated approach provide low loss high speed routing with short SOAs integrated primarily to enhance extinction. Better than -38dB signal to crosstalk ratio has been achieved for each of the ten channels. An input power dynamic range of greater than 10dB is observed for penalties of less than 0.5 dB at the aggregate 100 Gb/s /port data rate.

An optical switch fabric is regarded as a potential key component for future optical interconnects and access networks to meet the substantial and increasing demand for communications bandwidth[1]. Packet switches with nanosecond reconfiguration times are of particular interest and therefore semiconductor optical amplifier (SOA) and Mach-Zehnder interferometer (MZI) based switches have received much attention. However, the ultimate port count of SOA switches is restricted by the accumulation of noise and distortion[2]; while the scalability of MZI switches is limited by the poor crosstalk performance and high insertion loss[3].

We therefore have proposed a novel MZI-SOA hybrid approach, using dilated MZI switches to route signals and using short SOAs in between to enhance extinction and compensate MZI losses with reduced amplified spontaneous emission (ASE) noise[4]. A schematic of the operating principle of the hybrid design is shown in Fig. 1(a). Using this approach, a monolithically integrated 2×2 MZI-SOA hybrid switch module has been fabricated, as shown in Fig. 1(b). The routing performance of a single wavelength has been reported with up to -40dB extinction/crosstalk ratio, 3ns switching times, and almost penalty-free operation[5]. In this paper, we demonstrate the first 10×10Gb/s dense wavelength-division multiplexed (DWDM) routing using the monolithic 2×2 hybrid switch. Crosstalk performance for all the ten channels is assessed and penalties are measured.

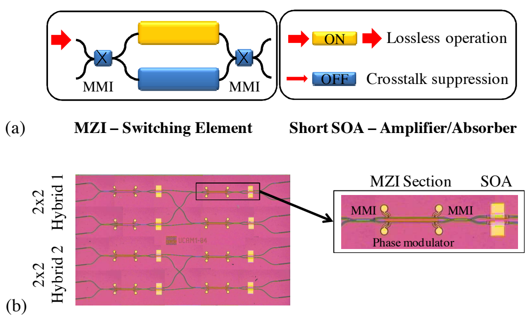

Fig. 1: (a) Schematic of operating principle. (b) Photograph of the fabricated hybrid switch.

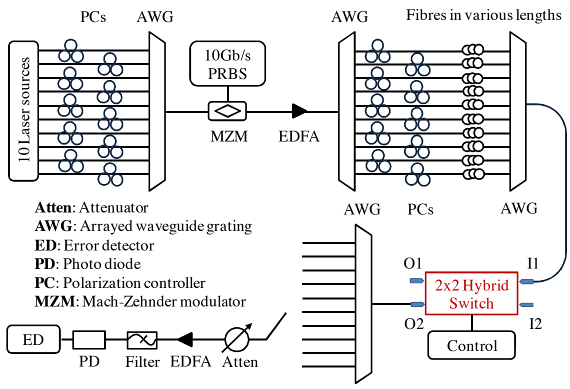

Fig. 2: Schematic of the experimental test-bed.

The switch device was designed and fabricated on a multi-project wafer using a generic foundry process within the EU FP7 PARADIGM project[6]. The chip comprises two dilated 2×2 hybrid switches and each is 2mm × 6mm in size. The 2x2 switch comprises four MZIs each output of which being followed by a 170μm long SOA gate. An MZI structure comprises two MMI couplers, two 800μm long phase modulators and input/output passive waveguides. The SOAs act to provide gain in the ON state but also provide significant crosstalk suppression in the OFF state.

A schematic of the experimental test-bed is shown in Fig. 2, where an array of 10 tunable lasers is operated at wavelengths from 1547.7 nm to 1554.9 nm with 100GHz spacing. The ten channels are combined by an arrayed waveguide grating (AWG) and a 2^{31}-1 pattern length 10Gb/s pseudorandom bit sequence (PRBS) is imposed by a Mach-Zehnder modulator. The fibers carrying the different wavelengths between the two additional AWGs differ in length so as to decorrelate the channels. This produces 100Gb/s aggregate DWDM data. Lensed fibers are used to couple light in and out of the chip. The switch is mounted on a thermoelectric cooler and operated at 20°C.

The DWDM crosstalk performance is first assessed by comparing the power at both output arms of the switch as a function of wavelength. The device configuration state (bar or cross state) can be switched by tuning the biasing conditions of the SOAs (0mA to 14mA) and phase modulators (-0.5V to -6.5V). It can be seen from Fig. 3 that the crosstalk ratio of the ten wavelengths lies between -38dB to -40dB and up to 42dB signal to noise ratio in a 0.1 nm bandwidth is achieved. The crosstalk of the dilated MZI structure is around 20dB and the short SOAs provide 18dB extinction enhancement. The measurement is performed with an aggregate optical input power of 8dBm (-2dBm per channel on average). Higher input power leads to a reduced crosstalk performance due to SOA power saturation.

By placing an AWG at the switch output, the routing performance of each sub-wavelength can be evaluated separately, by connecting to an optically pre-amplified and filtered receiver and error detector. Fig. 4 shows the switch power penalty at a BER of 10^{-9} as a function of on-chip input power per wavelength for both single and 10 wavelength with the switch operating in the cross state. It can be seen that the single wavelength input power dynamic range (IPDR) exceeds 26dB for a power penalty less than 0.5dB. The multi-wavelength operation however sees a more restricted operating regime owing to the increased aggregate optical power. The IPDR curve of channel 4 (1550.1 nm) shown in Fig. 4, which represents an average performance in the 10 channels, has a dynamic range of more than 10dB. The worst case is channel 8 (1553.3 nm) but still achieves penalties less than 0.3 dB with a dynamic range of 8dB. When routing 100Gb/s DWDM data, the switch device only consumes 0.3pJ/bit energy. The excellent performance and reduced power consumption are attributed to the use of short SOAs.

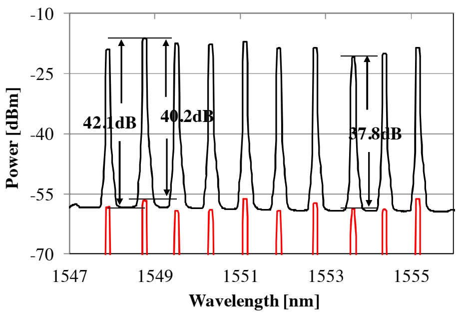

Fig. 3: Crosstalk measurement of 10 channels (the upper black curves represent the routed signal, while the lower red show the crosstalk signal).

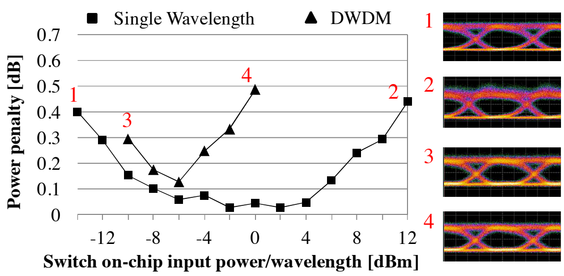

Fig. 4: IPDR curves for both single wavelength and DWDM operation eye diagrams shown for the numbered operating points.

In conclusion, better than -38dB crosstalk ratio and large IPDR (in excess of 10dB for less than 0.5dB penalty) has been reported for a monolithic 2×2 hybrid MZI-SOA switch routing 100Gb/s DWDM data. The excellent performance demonstrates this to be a promising approach for large-scale high-bandwidth monolithic circuit design.

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