Dilated 4×4 Hybrid MZI-SOA Switch with Relaxed Active Bias Control

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Increasingly complex and high capacity optical switch fabrics are being proposed and demonstrated for high-bandwidth data streams in datacentres [1]. Mach-Zehnder interferometer (MZI) and semiconductor optical amplifier (SOA) based switches have received much attention owing to their nanosecond response time which is essential for packet switching [2]. However, the scalability of MZI switches is inherently limited by insertion loss and accumulated crosstalk, whilst the scalability of SOA switches is restricted by accumulated noise and distortion.

We therefore have proposed a hybrid MZI-SOA approach, where MZIs are implemented as 1×2 or 2×1 low-loss switching elements, minimising crosstalk by using a single input, and where short SOAs are included as gain or absorption units, offering either loss compensation or crosstalk suppression though adding only minimal noise and distortion [3]. Using this approach, a 2×2 hybrid building block has been built by connecting four MZIs and eight SOAs in a dilated Beneš structure. This exhibited a -40dB extinction/crosstalk ratio and lossless operation [4]. The schematic of a 4×4 switch based on this approach and consisting of four 2×2 dilated hybrid building blocks is shown Fig. 1(a). For multi-stage networks such as this, it has been shown that active power monitoring and bias control can be employed to maintain constant output power and extend the input power dynamic range (IPDR) [5]. In this paper, we demonstrate the first current controlled operation of this 4×4 hybrid switch and investigate the control tolerance.

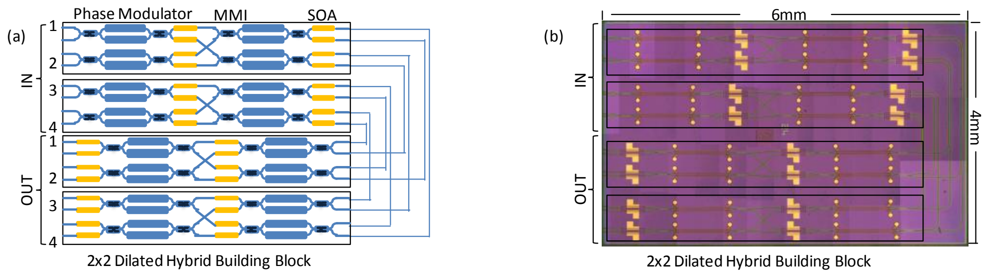

Fig. 1. (a).Schematic of 4×4 switch (b) Photograph of the fabricated hybrid switch

The switch was designed and fabricated on a multi-project wafer using a generic foundry within the EU FP7 PARADIGM project [6] with a sector size of 4mm×6mm. 1000/900µm long MZIs are used as 1×2 or 2×1 switching elements and 230/250µm long SOAs provide 5/6.3dB gain with 15mA/17mA bias currents to compensate loss from passive components. The slightly longer SOAs (250µm) are placed before the folded shuffle network to compensate for excess loss.

Power variation at the input causes fluctuation in the output power which in turn requires more demanding receiver performance levels or which leads to signal degradation in the following active components. It is therefore highly desirable to maintain a constant output power for a range of input powers. The first and second stage SOAs are therefore calibrated to select the optimum bias condition for various input powers. The calibration is performed with a 10 Gb/s NRZ signal at a wavelength of 1535.9nm. Lensed fibres are used to couple light in and out of the switch chip. The switch chip is mounted on a thermo-electric cooler and operated at 20^{0}C. The optical transfer function is evaluated for a broad range of currents and input powers. Fig. 2(a) shows the optical transfer function as the first and second stage SOA currents are varied, all other SOAs being biased at 15mA. Also shown is the transfer function for the controlled condition whereby the output power is fixed at -6dBm for a 10dB range of input power by varying the first and second stage SOA currents.

The IPDR with constant (15mA/17mA) and controlled current operation is shown in Fig. 2(b). At lower input power, it is not possible to achieve the desired constant output power owing to the limited gain from SOAs. The optimised bias current for first and second stage SOAs is selected here to minimise power penalty. The IPDR for a penalty of less than 0.2dB has been extended from 4dB to 8dB by implementing the active bias control. The power penalty improvement is significant at high powers because there is less amplifier-induced distortion as the SOA bias currents are lower. The tolerance of the bias control depends on the input power. Fig. 2(c) show a detailed penalty map for the active bias control as a function of both input power and bias variation. A 5mA bias current range is shown to maintain the power penalty below 0.2dB, this being a relatively relaxed tolerance in terms of the necessary current control.

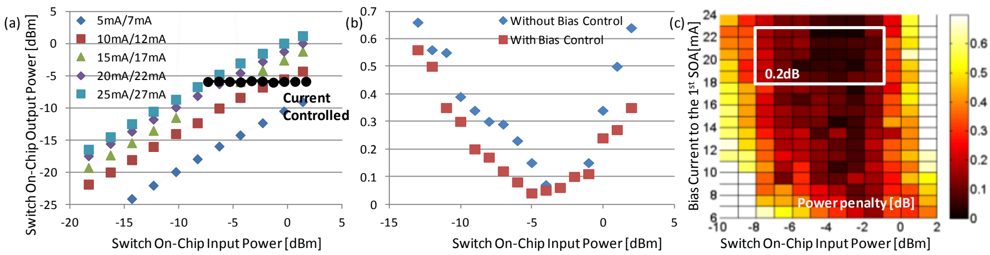

Fig. 2. (a) Static transfer function of the switch for varied and controlled current (b) Input dynamic range for the switch with fixed and controlled current operation (c)Penalty map as a function of input power and bias current.

In conclusion, this paper presents the active bias control for the 4×4 hybrid MZI-SOA switch chip. By controlling the injection current of the first and second stage SOAs, the fixed output power is achieved for a 10dB range of input power, and IPDR for a penalty less than 0.2 dB is extended from 4dB to 8dB with 5mA control current tolerance. This extended IPDR enables the scalability of the hybrid optical switch.

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