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Integrated 2 × 2 quantum dot optical crossbar switch in 1.55 μm wavelength range

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A highly compact quantum dot semiconductor optical amplifier based crossbar switch is proposed, fabricated and demonstrated at a wavelength of 1550 nm. Power penalty measurements at 10 Gbit/s show minimal path dependence with values of 0.15 to 0.25 dB and an extinction ratio of 24 dB.

Introduction: High-capacity data transfer in storage area networking, high performance computing, and server networks is driving research into photonic switched interconnect solutions. Low-latency broadband semiconductor optical amplifier (SOA) based switches have received particular attention owing to the promise of low control complexity [1] and monolithic integration, which may in turn enable enhanced power efficiency in next-generation interconnection technology. SOA-based integrated switches have been demonstrated using broadcast-select [2] and crosspoint architectures [3]. However, such approaches are complex to scale, with numbers of waveguide crossings and multiple control signals increasing rapidly with connectivity. To date, epitaxial design for SOA-based switches has commonly impaired saturation properties and compromised performance at high data rates. Considerable recent research attention has therefore been focused on quantum dot (QD) amplifiers owing to their broadband amplification, low distortion and low noise [4]. To this end, a two-input two-output quantum dot space broadcast and select switch was realised in the 1300 nm wavelength range [5]. In this Letter we demonstrate a highly scalable two-input, two-output quantum dot crossbar switch design at 1550 nm for low power penalty routing at 10 Gbit/s, providing an important building block for larger switch matrices.

Device: The crossbar circuit is shown in Fig. 1. The electrode geometry is specified to address common waveguides, simplifying control and minimising the number of electrical connections. The two-input two-output (2 × 2) crossbar is 3.2 mm in length with gate length of 1.4 mm. Input and output waveguides are placed on a 0.25 mm pitch for ease of fibre access. Fig. 1a shows the top view scanning electron micrograph. Fig. 1b shows the waveguides and the light-shaded gold electrodes in schematic view. The InGaAsP/InP epitaxy comprises a five-stack quantum dot active layer as reported in [6], with the exception here that it is embedded in a Q1.15 confinement layer. A three-step reactive ion etch is performed to define electrically-isolated deep and shallow amplifying waveguides in the required interconnection topology. Multimode interference couplers are employed as splitters and combiners. Separately addressable gate waveguides enable the reconfigurable routing.

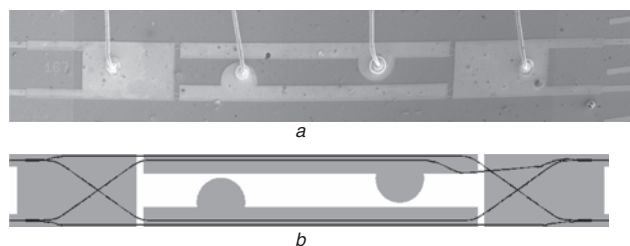


Fig. 1 Monolithically integrated crossbar switch

a Top view image
b Schematic waveguide and p-metal layout

Transmission at 10 Gbit/s: The experimental arrangement to assess the integrity of routed data is shown in Fig. 2. Power penalty measurement was performed using a Finisar transceiver to measure a 10 Gbit/s data rate signal with a $2^{31} - 1$ pseudorandom bit sequence. Polarisation is carefully aligned. Additional fibre amplification is provided to overcome fibre chip coupling losses and on-chip losses from splitters and combiners. In-fibre input powers of +10 dBm at 1550 nm are used, and a fibre coupling loss of 8 dB is estimated from photocurrent measurements. Lensed fibres are used to characterise all the switching paths. The circuit is operated at a temperature of 17°C. Input and output sections

are biased at 160 mA. On-state and off-state gate currents are set to 0 mA and 120 mA, respectively, enabling extinction ratios within the range 23.8 to 24.3 dB for the switch paths. The output signal from the switch circuits is optically filtered for broadband noise rejection to assess the bit error rate.

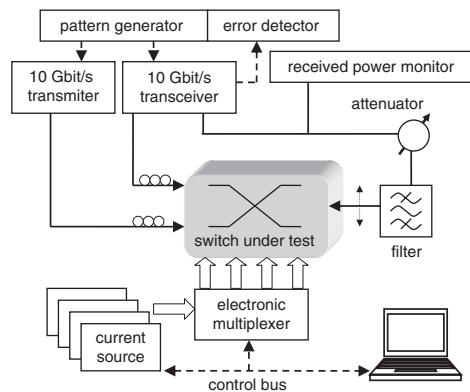


Fig. 2 Experimental arrangement for switch assessment

Power penalty performance is assessed from the bit error rate dependence on received power shown in Fig. 3. Path dependent power penalties of 0.15 to 0.25 dB are observed with no evidence of distortion. The low values of power penalty may be attributed to a modest level of amplified spontaneous emission and a high optical saturation threshold. These attributes may be attributable to the quantum dot gain medium [4].

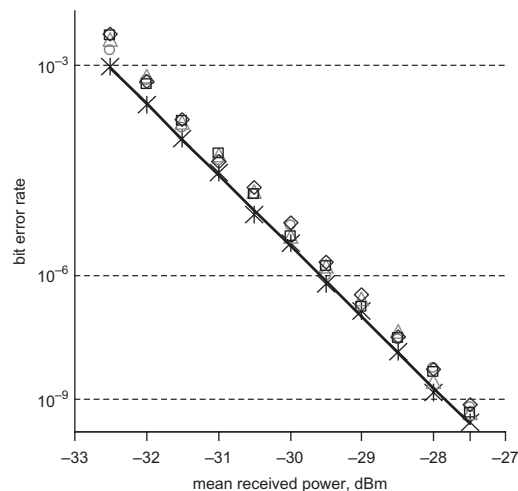


Fig. 3 Bit error rates against mean received power for each switch path

Trend-line given for back to back data to assist the eye
Top left input: bar-state (squares), cross-state (circles)
Bottom left input: bar-state (triangles), cross state (diamonds)

Conclusion: The first 1.55 μm quantum dot semiconductor optical amplifier crossbar switch design is proposed, fabricated and demonstrated. A switching extinction ratio of 24 dB is achieved and power penalties are measured for the four paths with values between 0.15–0.25 dB, indicating negligible path dependent penalty.

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