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Low Penalty Cascaded Operation of a Monolithically Integrated Quantum Dot 1x8 Port Optical Switch


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Abstract A novel Quantum Dot monolithically integrated 1x8 switch is shown to provide robust routing of data at 10Gb/s modulation rates. Two cascaded switches providing, 1x64 functionality, operate with a power penalty of only 0.9dB.

Introduction There has recently been much interest in the development of high performance semiconductor optical amplifier (SOA) based switches for computing and other optical networking applications as they offer high on-off switching ratios and provide inherent optical gain. Demonstrations have been made both for switches based on discrete components and also partially populated integrated solutions. To date however monolithic crosspoint devices have been formed with port counts of 4x4, and recently 1x8 port splitters made by active passive integration in quantum well material have been demonstrated as enabling components for 8x8 switches.

The use of quantum well active regions has proved to be successful, but recently quantum dot (QD) materials have been found to be of particular interest in SOA switches partly because of the enhanced performance that QD amplifiers have shown in terms of higher saturation powers, better distortion and lower noise figures. For example, QD amplifiers have been shown to exhibit significantly enhanced dynamic range, gain and reduced distortion allowing an increase in loss budget in PONs for example, of 17dB. In addition, other recent work has lead to the demonstration of 4x4 QD-based switches and shown the potential for uncooled QD SOA operation.

In this work therefore we report the first QD 1x8 port integrated switch, suitable for a variety of reconfigurable star, PON and switch applications. We demonstrate the potential for cascading this device to enable the construction of larger bespoke switch architectures.

The 1x8 switch, which is made of a five stack QD active layer embedded in a Q1.15InGaAsP separate confinement heterostructure, comprises an input waveguide with a tree of 3dB couplers providing 8 output branches. Each of the output waveguides has separate electrical contacts, allowing independent control of each of the outputs. The input and output waveguides are angled to minimise back reflections.

Experiment A chip containing two 1x8 integrated switches, shown in figure 1A, is used as this allows cascaded performance of multiple devices to be investigated. 4 controllable lensed fibres are used, to allow simultaneous access of an input and output waveguide of both devices and to test different paths. Figure 1B shows the experimental setup in which a 10Gb/s pseudo random bit sequence from a bit error rate test set (BERT) is used to modulate a Mach-Zehnder modulator whose optical input is from a tunable laser. The output from the modulator is then amplified with an EDFA, optically filtered and attenuated to provide a variable input power to the switch. The output is then filtered, and fed via a variable attenuator to an optically pre-amplified receiver allowing the performance of a 1x8 switch to be investigated using the error analyser on the BERT.

The output from the first optical switch can be looped back to the second 1x8 switch, allowing cascaded performance to be measured.

The electrical contacts of the optical switches are driven by a switchable power supply so that the temporal performance of the switch can be studied. In the case of a cascaded switch an EDFA and optical filter are used to compensate for the fibre coupling loss at the angled facets.

Results The on chip performance of the switch has been characterised after removing fibre coupling losses, which are estimated from photocurrent measurements to be 12dB in this device.

The 1x8 switch has 3 cascaded 3dB splitters in each path, introducing 9dB of loss, and, together with some excess loss within the switch, this yields a net
Measurements at 1535nm and 1560nm also show input variation, for an input signal at 1550nm. little with input power, being less than 1dB for a 10dB through being limited by the available power which can be cascaded demonstration shows great promise. With additional loss and additional EDFA ASE noise the compensate for the coupling losses. Despite this EDFA and filter between the two switch stages to integrated 8x8 switch must be substituted by fibre, an in this case the waveguides connecting the cascaded pair of switches has been studied. The potential of the 1x8 switch can be seen by switching packets to a chosen output port of the switch. In this case, the output port drive current is switched from 0mA in the off state to 180mA in the on state. This current swing is currently limited to 10ns by the driver and electrical drive parasitics, which limits the switching times. However improved performance can be expected as QD based switches have been shown to have rise and fall times of 1ns. Figure 5 shows the output of the switch under dynamic operation. The switch produces an optical extinction of 14dB.

Conclusions
A Quantum Dot monolithically integrated 1x8 switch is presented as a component for large integrated optical switches and optical selectors. The switch has a 3dB spectral bandwidth of > 65nm and a penalty of less than 0.4dB, with a 1dB input saturation power of 5dBm. Two such cascaded switches exhibit a power penalty of only 0.9dB making them suitable candidates for a 64 way low-loss splitter in, for example, PON applications.

References