Reflective Semiconductor Optical Amplifiers in Passive Optical Networks

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ABSTRACT
Reflective Semiconductor Optical Amplifiers (RSOAs) offer a cost effective wavelength agnostic transmitter for applications within wavelength division multiplexed passive optical networks (WDM PONs). The parametric and systems performance of bulk active buried heterostructure RSOAs across the S, C and L wavelength bands is given.
***Keywords**:* Semiconductor Optical Amplifiers (SOAs), Fiber-to-the Home (FTTH), Passive Optical Networks (PONs), Wavelength Division Multiplexing (WDM).

1. INTRODUCTION

The growing demand for high speed access services has driven the deployment of Passive Optical Networks (PONs) [1] since the amount of terminal equipment between the core and access layers of the network is minimised [2,3]. The RSOA is especially relevant to future PONs scenarios providing a colourless amplifier which can obviate the need for tuneable of fixed laser sources at the customer premises. The RSOA can be seeded with a single continuous wave source at the ONU (Optical Network Unit) shared among a number of users and can simultaneously amplify and modulate that seed to support a WDM overlay in a wavelength agnostic manner.

2. DEVICE STRUCTURE AND PARAMETRIC CHARACTERISATION

The RSOAs are based on an InP-based buried heterostructure (BH) design with a ~1.2µm wide InGaAsP tensile bulk active region. The active region is tensile strained to compensate the differences in confinement factor in order to minimize polarization dependency. The PL wavelength of the active region can be adjusted with the additional necessary additional modifications so that operation over the desired band can be achieved. Devices with gain peaks at 1500nm and 1560nm resulting in contiguous operation over the S, C and L bands are discussed here. The RSOAs have a high reflectivity coating on one facet and an ultra low reflectivity coating ($<10^{-5}$) on the other. The input facet is angled and to achieve a normal and a 10 degree angled facet on the same device the gain region is curved close to the centre of the chip with a bend with radius of 3mm. To further reduce the effective facet reflectivity and improve coupling, the device output far field is reduced through the linear tapering of the active region is in the lateral direction from 1.2µm to approximately 0.45µm over 80µm approaching the angled facet. The key parameters of interest for an optical amplifier are gain, Noise Figure (NF), polarization dependent gain (PDG) and maximum saturable output power (Psat); with RSOAs, modulation bandwidth is also relevant. A parametric performance summary of the key operational parameters of a pigtailed TO style packaged RSOA device at a drive current of 80mA is shown in Figure 1 and Figure 2. S-band devices (Figure 1) exhibit excellent gain (over 20dB from 1470 nm upwards), with P_{sat} rising to a maximum of 7.5dB at 1530nm. The NF peaks at 10.5dB at 1465nm but is generally <10dB. Small signal PDG is less than 2.8dB across the band and ripple is less than 2.2dB; both will reduce substantially in operation as the gain is compressed. For C/L-band devices (Figure 2) at a drive current of 50mA, more than 20dB of gain can be observed from 1535nm upwards, with P_{sat} rising to a maximum of 6dB at 1580nm. The NF peaks at 11dB at 1530 nm but is generally <10dB. Finally, the PDG and Gain Ripple are lower than 1.3dB and 1.1dB respectively.

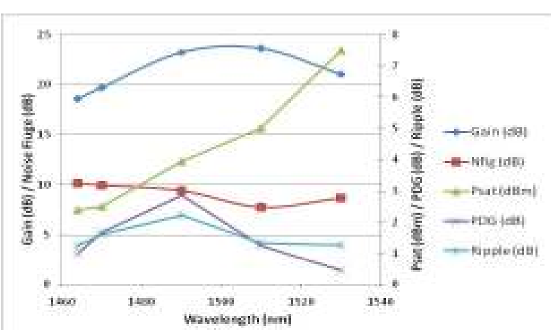

Figure 1: Parametric Characterisation of RSOA in S-band

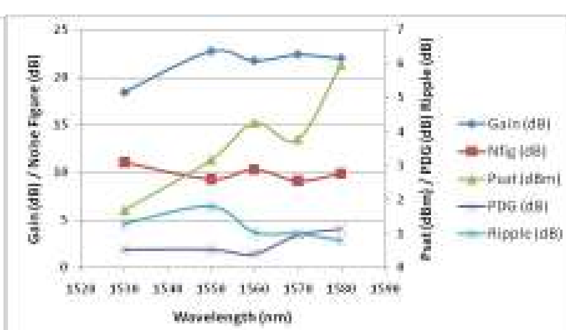

Figure 2: Parametric Characterisation of RSOA in C/L-band

3. RSOA WDM PON SYSTEMS PERFORMANCE CHARACTERISATION

Wavelength seeded RSOA PONs share a CW seed source between many users. At each of the ONUs, an RSOA is used to amplify the seed signal and directly modulate it with data to be carried in the upstream direction [4][5][6]. The CW source can either be a laser or a broadband light source filtered by an optical multiplexer/de-multiplexer. The remainder of the transmission (backhaul and splitter) can be considered as a lumped loss and can be most readily emulated by two Variable Optical Attenuators (VOAs); at low data rates (1.25Gbit/s) dispersion is not significant and was not considered. The seed wavelength was injected into an RSOA, directly modulated at 1.25Gbits/s with a NRZ Pseudo Random Bit Sequence (PRBS) 2^{11}-1. An ETS3869 driver, which provides control over the bias current (I_{bias}) and the data modulation, was used to modulate the RSOA. Control over the RSOA chip temperature is also provided by an external controller; the RSOA performance was characterised at a chip temperature of 25ºC. After passing through a variable optical width Band-Pass Filter (BPF), the upstream modulated signal was received at the OLT using combination of an Avalanche Photodiode (New Focus 1647 APD Photo-receiver) followed by a limiting amplifier. This output was input to an Agilent N4903A J-BERT Bit Error Rate Analyser so that the transmission path performance could be quantified through the Bit Error Rate (BER) performance. The BER was measured for different levels of optical power injected into the RSOA enabling a sensitivity characterisation of the upstream transmission to be evaluated. Figure 3 depicts a representative measurement of an S-band RSOA (at 1490nm) illustrating the return path loss capability (PLC, defined as the loss margin available at the output of the RSOA) as a function of seed signal strength delivered into the RSOA, measured as the difference between the output power of the RSOA and the receiver sensitivity. The receiver sensitivity varies slightly with input power but is nearly constant at around -30dBm for 10^{-9} BER. This is a power penalty of only 1dB compared to a commercial lithium niobate M-Z modulator when used in place of the RSOA. The PLC performance is dictated mainly by the amplifier gain (at low signal levels) and by the P_{sat} value as the input seed signal strength increases. At high seed laser strengths, the PLC exceeds 35dB, reducing slowly as the RSOA enters saturation. To demonstrate the performance of the RSOAs over a range of wavelengths, the PLC was measured across the S, C and L bands using the two RSOAs for as a function of input power level versus wavelength for a seed laser power of -20dBm (Figure 4) which is typical in a system. Each device is capable of providing >25dB PLC over a 60nm span. The combination of the RSOAs provides PLC of >25dB over a wavelength interval of >120nm (1470 nm to 1590 nm).

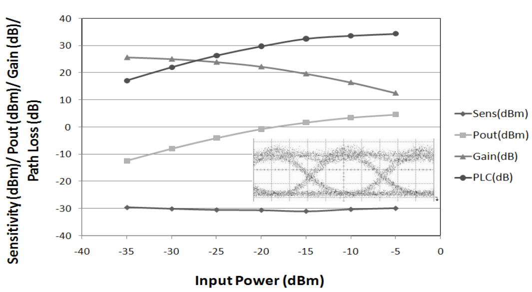

Figure 3: System characterisation versus input power for 1470 nm

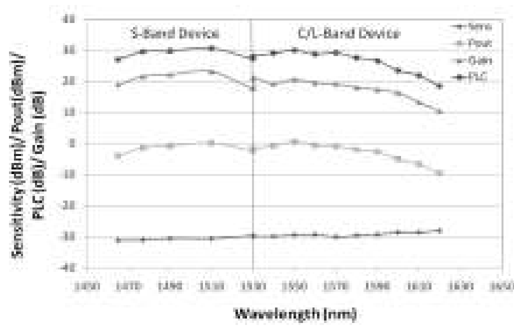

Figure 4: System characterisation versus wavelength

4. CONCLUSIONS

InP based buried heterostructure polarisation independent strained bulk RSOAs have been demonstrated which operate over >60nm with large return path loss capabilities. Devices have been fabricated with the necessary modifications to provide contiguous operation over the S, C and L bands using 2 devices.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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