Sixteen-Channel Wavelength Selector Monolithically Integrated on InP

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1. Introduction

Fast switching technology will soon be needed to handle the continuing growth of data traffic generated by new Internet-borne services. This technology has to be compatible with the constraints of packet applications. In the optical domain, Semiconductor Optical Amplifiers (SOA's) used as optical gates can achieve both space and wavelength switching, with time responses in the *ns* range. Here we present the realisation of a sixteen-channel wavelength selector, fabricated by monolithic integration on InP of two phased-array wavelength demultiplexers butt-coupled to 16 SOA's. Among the various advantages of the wavelength selector over tuneable filters, the gain of the SOA's can compensate for the loss of the passive sections, making possible zero-loss operation, and even gain. However, as previously said, a key feature of the wavelength selector is its fast switching speed that is limited only by the rise- & fall times of the SOA's.

The potential of monolithic integration on InP for the fabrication of wavelength selectors was already demonstated with the realisation of a 4-channel device [1]. The butt-coupling technique was used to achieve high performance: zero-loss operation at low driving current, low crosstalk and compactness. The same technology has been successfully applied to the realisation of a 16-channel wavelength selector.

2. Device fabrication

The passive sections of our device consist of a deeply etched structure [2], and the active sections consist of a separate confinement heterostructure with a low tensile-strained bulk active layer [3]. The layers of the passive sections and the top layers of the SOA's were grown using metal organic vapor phase epitaxy, and the layers of the active structure were grown using gas-source molecular beam epitaxy. A specific integration scheme has been developed to ensure low propagation loss in the passive section (~ 3 dB/cm), as well as low and reproducible coupling loss and low reflectivity at the transition with the active one [4]. This process combines growth of undoped cladding layers in the passive sections with patterning of all stripes in a single lithographic step, leading to self-aligned active and passive sections.

3. Device characteristics

The target wavelength spacing of our 16-channel wavelength selector is 100 GHz (0.8 nm) with a free spectral range of 18 nm around 1.55 μm. It consists of two phased-array wavelength demultiplexers, with 80 waveguides in the gratings, and 16 SOA's each 470 μm long. The minimum radius of curvature of the bent waveguides was 100 μm whereas the pitch of the SOA's was 150 μm. The figure 1 shows the chip after cleaving and mounting; its total size is only 4.2 mm x 4.6 mm.

4. Experimental results

The correct operation of the wavelength demultiplexers was first checked by measuring the filtered amplified spontaneous emission (ASE) of an SOA through the two demultiplexers, by simply biasing one SOA and analysing the signal with an Optical Spectrum Analyser at the input and output of the device. Figure 2 shows the good behaviour of the demultiplexers, especially in terms of spectral matching.

Figure 3 shows the fibre-to-fibre insertion loss of the wavelength selector at room temperature with driving current. The signal was coupled in and out of the device with lensed fibres and the optical power at the input was –13 dBm. The channels, or SOA's, are numbered from 1 to 16, the first one corresponding to the lower wavelength (1512.79 nm) and the last one to the higher wavelength (1524.68 nm). Though all SOA's work well, gain curves of only 14 channels are plotted since the passive waveguides connecting SOA's 5 and 6 to the multiplexer have been damaged during mounting. We can see that zero insertion loss was achieved for injected current between 38 mA and 50 mA for the 14 working channels. When the current is increased to more than 100 mA, optical gain of at least 5 dB can be obtained. The gain difference between all channels is below 3 dB for a given current, the central channels having more gain than the external ones. This effect mostly results from the loss curve of the two demultiplexers with channel number, cumulated with the gain curve of the SOA's, which is centred around 1520 nm at 50 mA.

The polarisation dependent loss (PDL) of the wavelength selector has also been investigated, using an optical loss analyser coupled to a polarisation controller that automatically scans all states of polarisation at the input of the device. Figure 4 shows the PDL of the 14 working channels at 50 mA bias current. The PDL ranges from 1.3 dB to 3.2 dB, with a mean value of 2.2 dB. Note that the measurement is very sensitive to the signal wavelength due to a slight shift between TE and TM responses of the demultiplexers: a shift of 0.05 nm of signal wavelength creates a PDL variation of 0.8 dB.

From the wavelength selectivity point of view, the crosstalk of the wavelength selector from one selected channel to a non-selected one is between –35 dB and –75 dB, depending on the channels which are considered. However, the mean value calculated from the different possible combinations is –49 dB, as shown on figure 5. The maximum measured crosstalk value for this device is worse than what was reported on the 4-channel device, which was –40 dB. This is due to secondary peaks in the spectral responses of the demultiplexers that coincide with the signal wavelength of one channel.

In a last experiment, the saturation power at the input of the wavelength selector was measured on one channel at 50 mA bias current by varying the input power from –20 dBm to 5 dBm using an EDFA followed by a filter and an attenuator. On figure 6 is plotted the gain curve for channel 8, showing a 3 dB input saturation power of about –4 dBm (in fibre).

5. Conclusion

Zero-loss operation at only 50 mA driving current was achieved with good homogeneity on a 16-channel wavelength selector. Though this was reached with only 14 channels due to passive waveguides that were damaged during mounting, it demonstrates the potential of InP for large-scale monolithic integration, making possible the realisation of high-performance and compact devices achieving advanced functionality.

[1] R. Mestric, et al. « Loss-less four-channel wavelength selector monolithically integrated on InP », *Proc. 24th Optical Fiber Com. Conf. (OFC'99), ThB2-1*, (San Diego, Ca), Feb. 23-26 1999

[2] R. Mestric, et al. « Up to 16-channel phased-array wavelength demultiplexers on InP with -20 dB crosstalk », *Proc. 8th Eur. Conf. on Int. Opt. (ECIO'97), EThE3-1*, (Stockholm, Sweden), Apr. 2-4 1997

[3] J.-Y. Emery, et al. « High performance 1.55 μm polarization-insensitive semiconductor optical amplifier based on low-tensile-strained bulk GaInAsP », *Electronics Letters*, June 1997, vol. 33, no. 12, pp 1083-1084

[4] F. Pommereau, et al. « Optimisation of butt-coupling between deep-ridge and burried ridge waveguides for the realisation of monolithically integrated wavelength selector », *Proc. 11th Conf. on InP and Related Materials (IPRM'99), WeA1-7-1*, (Davos, Switzerland), May 16-20 1999

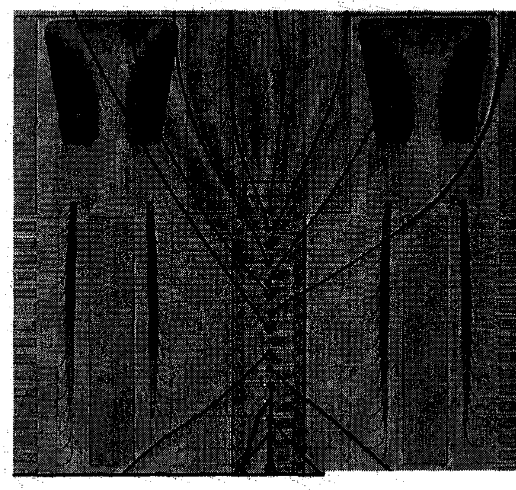

Fig. 1 : Photograph of the 16-channel wavelength selector, electrically connected via bounding wires.

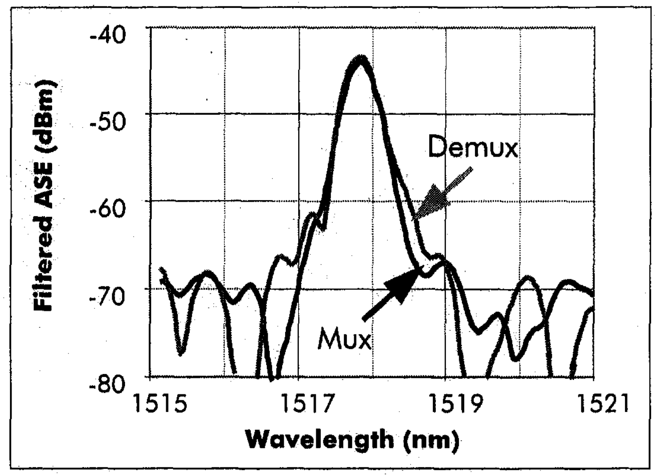

Fig. 2 : Filtered ASE of one of the SOA's through mux and demux of the wavelength selector, showing excellent matching of the spectral responses.

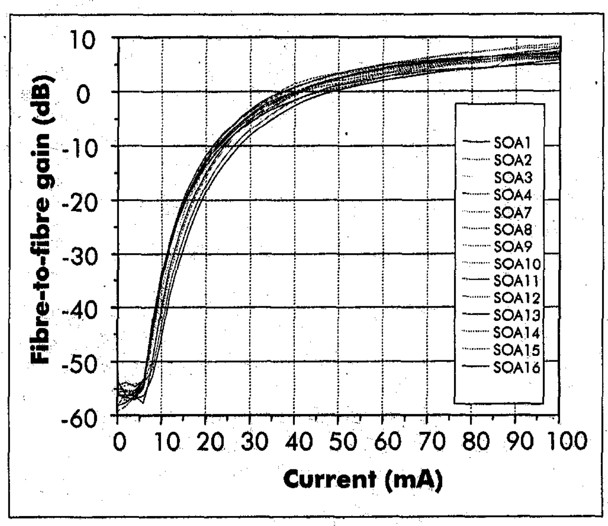

Fig. 3 : Gain curves of 14 channels of the wavelength selector vs bias current, for -13 dBm input power and optimised polarisation.

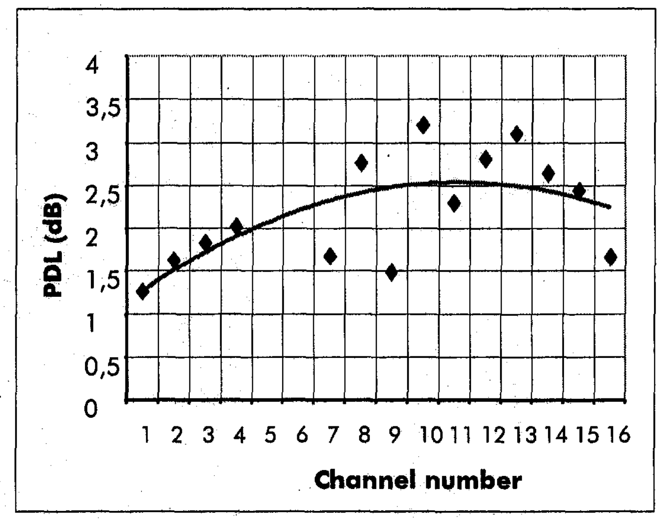

Fig. 4 : Polarisation dependent loss of 14 channels of the wavelength selector, for -13 dBm input power and 50mA bias current.

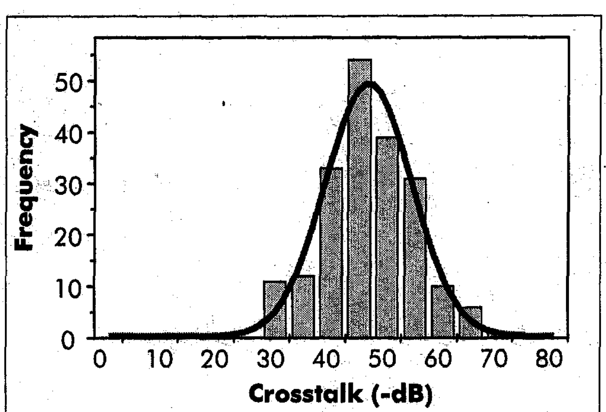

Fig. 5 : Crosstalk statistical measurement on all channels of the wavelength selector.

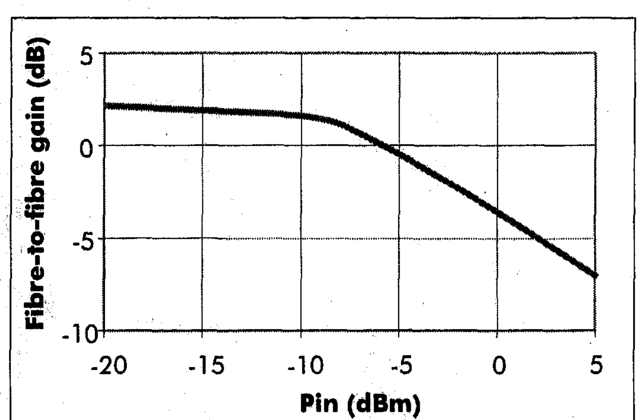

Fig. 6 : Fibre-to-fibre gain vs input power for one channel and 50 mA bias current