*Summary:* We have proposed a novel scheme for in-line optical regeneration in RZ transmission systems. The scheme is based on the principle of black box RZ/soliton conversion, synchronous modulation and filtering, followed by reverse soliton/RZ conversion. Potential applications range from SMF-based terrestrial systems to dispersion-managed soliton systems for global-distance transmission.

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## Fused III-V vertical coupler filter with reduced polarisation sensitivity

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A novel fused InGaAsP/InP-AlGaAs/GaAs vertical coupler filter is demonstrated. By using the large material dispersion between InGaAsP and AlGaAs and similar waveguide geometries, a 3.6nm bandwidth and 5nm polarisation dependent wavelength shift using a 1.1mm long fused vertical coupler has been achieved.

*Introduction:* Dense wavelength division multiplexing (DWDM) requires narrowband optical filters and add/drop channel multiplexer/demultiplexers. Asymmetrical vertical directional coupler filters [1 – 4] using two dissimilar waveguides on III-V semiconductors are promising because of their inherent on- chip integration with other optoelectronic devices and ease of fabrication. In conventional vertical coupler filters, both waveguides are fabricated using the same material system, InGaAsP/InP [2 – 4] or AlGaAs/GaAs. A narrow bandwidth requires a strong waveguide dispersion difference between two waveguides. This is usually achieved using dissimilar waveguide geometries. One of the waveguides is narrow with high index contrast. And the other wide with low index contrast. There are several obstacles to the use those vertical coupler filters, including a strong polarisation dependence (the centre wavelength shift for TE and TM modes is > 60nm), a large difference in coupling efficiency between the two dissimilar waveguides, and the difficulty of launching the light into and coupling light out of two very close waveguides. Since the polarisation dependence and different coupling efficiency come from the strong asymmetry of two waveguide geometries, these problems can be solved if the two waveguides have similar structures and indices, but they have a large material dispersion difference.

In this Letter, we report a novel vertical coupler filter (VCF) based on wafer fusion technology [5, 6], which combines two different material systems: InGaAsP/InP and AlGaAs/GaAs. By utilising the large material dispersion difference between InGaAsP and AlGaAs around 1.55μm wavelength to realise narrowband filters using similar waveguide geometry which ensures that both waveguides have almost identical waveguide dispersions (same birefringence), it is possible to considerably reduce the polarisation sensitivity of the vertical coupler filter. Furthermore, wafer fusion can facilitate the separation of the waveguides at the input and at the output [7, 8].

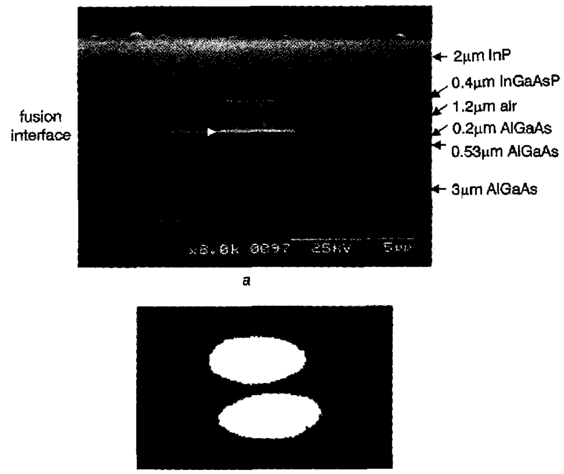


**Fig. 1** *SEM photograph of fused InGaAsP/InP-AlGaAs/GaAs vertical coupler filter and near field of fused coupler filter*

*a* SEM photograph
*b* Near field

*Fabrication:* The structure of the fused vertical coupler filter is shown in Fig. 1. The upper InGaAsP/InP waveguide consists of a 0.4μm InGaAsP ($\lambda_{gap}$ = 1.45μm) guiding layer and a 1.2μm InP cladding layer, which was grown on an InP substrate by metal organic chemical vapour deposition (MOCVD). The lower AlGaAs/GaAs waveguide, grown on a GaAs substrate by MBE, includes a 3μm $Al_{0.6}Ga_{0.4}As$ isolation layer, 0.53μm $Al_{0.1}Ga_{0.9}As$ core layer, 0.2μm $Al_{0.5}Ga_{0.5}As$ cladding layer and 200nm GaAs cap layer that serves to protect the AlGaAs layer from oxidation. The two waveguides are phase matched around 1.55μm. 3D BPM calculations predict a 1mm coupling length. To fabricate the fused vertical coupler filter, rib waveguides with a ridge height of 1.2μm and 3–6μm widths on an InP sample are formed using selective wet etching. After the standard cleaning procedure, the InP sample with rib waveguides and the GaAs sample are fused together at a temperature of 630°C in a hydrogen atmosphere for 50min. Subsequently the InP substrate is removed by HCl etching. Fig. 1 shows the SEM photograph of the finished device.

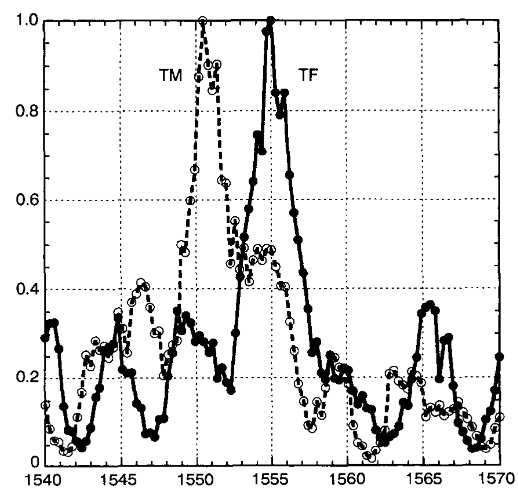


**Fig. 2** *Measured response of 3μm wide fused vertical coupler filter for TE and TM modes*

*Results and discussions:* The optical transmission of fused vertical coupler filters is measured with polarised light from a tunable semiconductor laser that is coupled to the filters via a singlemode lensed fibre. The light at the output of the filters is coupled to another singlemode lensed fibre connected to a detector. Fig. 1*b* shows the near field image with a ×80 objective at the output of the fused vertical coupler filter. The mode profiles of the two waveguides are very similar, which is important for realising polarisation independence and similar coupling efficiency. Fig. 2 shows the transmission data for TE and TM polarised light for a 3µm wide 1.1mm long fused filter. The 3dB bandwidths of the TE and TM modes are 3.6 and 3.3nm, which closely agree with the theoretical values of 3.8 and 3.5nm. The polarisation dependent wavelength shift is only 5nm. Theoretical calculations predict a 7nm shift and this polarisation dependence can be eliminated by a slight modification to the design by replacing the 1.45µm InGaAsP with 1.37µm InGaAsP. Since the material dispersion is increased when the wavelength is near the bandgap, the 3dB bandwidth is narrower for shorter wavelength. Fig. 3 shows the dependence of bandwidth on wavelength, which is agreement with the theoretical calculations.

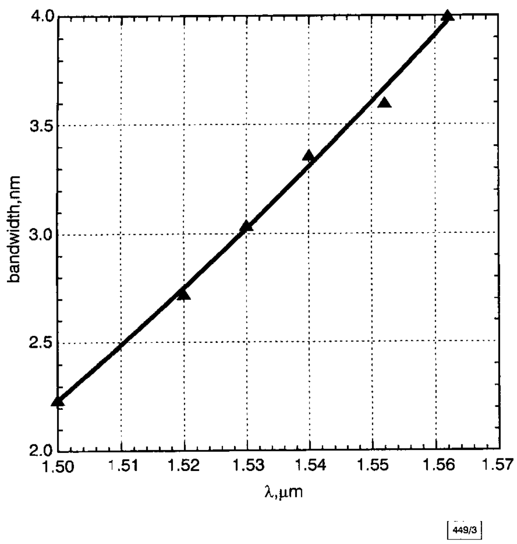


**Fig. 3** *Wavelength dependence of filter bandwidth*

*Summary:* A novel fused InGaAsP/InP-AlGaAs/GaAs vertical coupler filter with reduced polarisation dependence has been fabricated and characterised. The large material dispersion difference between InGaAsP and AlGaAs was used to achieve narrowband filters. A polarisation dependent wavelength shift of 5nm has been achieved. The corresponding wavelength shift in conventional vertical coupler filters is > 60nm. With an improved design, polarisation-independent and narrowband fused vertical coupler filters can be realised. These filters are promising components for future WDM systems.

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# Increased speed of semiconductor optical amplifier wavelength converter at multiple channels using Fabry-Perot and microelectromechanical filters

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A Fabry-Perot optical discriminator is used to reduce the pattern dependence of a semiconductor optical amplifier wavelength converter at 10Gbit/s. In conjunction with a voltage tunable microelectromechanical bandpass filter, this allows a reduction of conversion penalty for multiple wavelength channels.

Semiconductor optical amplifier based all-optical wavelength converters are being considered for used in reconfigurable nodes of future WDM systems because of their compactness, high-speed operation and low power requirements [1]. To be cascadable, semiconductor optical amplifiers (SOAs) have to have a modulation bandwidth that exceeds the bit rate of operation. In addition the wavelength converter should be able to convert an incoming data to one of many wavelength channels as specified by a circuit control signal.

High-speed operation can be obtained by using long semiconductor optical amplifiers, high currents, and high optical powers. Bit rates as high as 40Gbit/s have been demonstrated in SOAs [2]. It was recently demonstrated that a fibre Bragg grating optical discriminator placed after the converter can also increase the dynamic bandwidth and therefore the bit rate of operation of an SOA wavelength converter [3]. As described in [3] the discriminator converts the phase modulation that accompanies the converted signal to amplitude modulation to sharpen the transition edges between the 1 and 0 bits. This requires that the wavelength of the converted data match the transmission edge of the fibre grating such that the converted spectrum lies in the linear transmission region of the grating, making it difficult to tune to different channels.

Here we use a Fabry-Perot filter with a free-spectral range of 100GHz (ITU standard) as the optical discriminator. Hence the relative spectral position of the signal and Fabry-Perot transmission spectrum remains fixed as the wavelength of the converted data is changed from one channel on the ITU grid to the other. In addition we use a voltage tunable microelectromechanical filter for channel selection [4].

Fig. 1 shows a schematic diagram of the conversion experiment. 10Gbit/s NRZ data and a CW signal are launched into an SOA in a co-propagating configuration. The SOA is a fibre-pigtailed amplifier with an unsaturated gain of 26dB at 200mA. The bias of the SOA was 145mA. The optical power of the data and CW