Variations with size of frame: If N_c is modified, the size of the frame changes. Fig. 4 gives the BER for two hybrid turbo codes:

(i) BCR (32, 26, 4) and RSC (23, 35) with 416 and 832 bit frame sizes

(ii) BCH (16, 11, 4) and RSC (23, 35) with 88, 176 and 264 bit frame sizes

For a 176 bit frame size, we have added the curve which gives the frame error rate (FER). Thus, hybrid turbo codes can be used for short blocks.

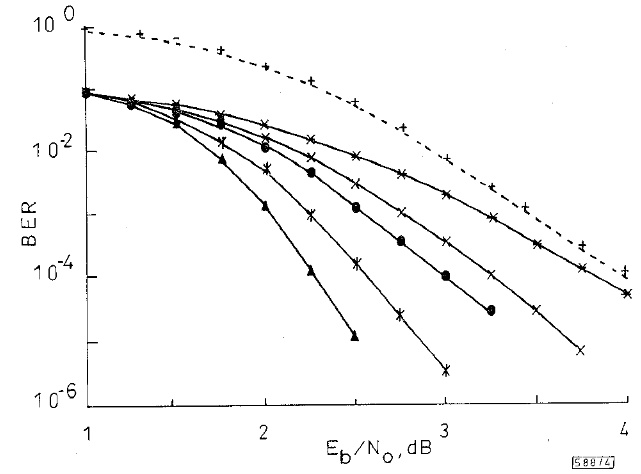

Fig. 4 *BER against frame size and signal to noise ratio with q = 4, R = 1/2 and after four iterations*

■ $K \times N_c = 416$
▲ $K \times N_c = 832$
× $K \times N_c = 88$
✳ $K \times N_c = 176$
● $K \times N_c = 264$
–×– FER = (176)

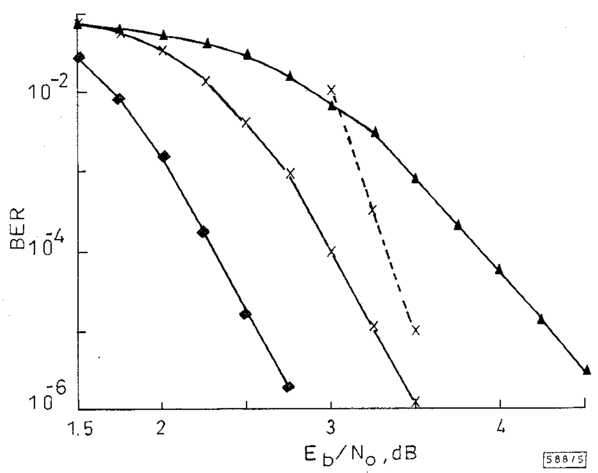

Fig. 5 *BER against code rate and signal to noise ratio for BCH (32, 26, 4) and RSC (23, 35) with q = 4 and after four iterations (R = 1/2, 2/3 and 3/4)*

◆ $R = 1/2$
× $R = 2/3$
▲ $R = 3/4$
–×– CC (133, 171 and $R = 3/4$) and RSC (255, 239, 8)

Variations with N_y: By puncturing Y, it is possible to change R_{RSC} (and R). Fig. 5 gives the BER of the concatenation of BCH (32, 26, 4) and RSC (23, 35), against different code rates. The results of the hybrid turbo code are compared with the serial concatenation of CC ($\nu = 6$, $R = 3/4$) and RS code (255, 239, $t = 8$), used for digital HDTV [8].

Conclusion: We have given some results concerning the performances of hybrid turbo codes. They indicate that this serial concatenation can favourably replace the 'standard scheme' built with a CC and RS code. We also showed that they could be used for short blocks.

2 September 1996
Electronics Letters Online No: 19961453

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Reduction of semiconductor laser amplifier induced distortion and crosstalk for WDM systems using light injection

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Indexing terms: Semiconductor optical amplifiers, Crosstalk, Wavelength division multiplexing

Semiconductor laser amplifiers cause both distortion and crosstalk in WDM systems due to gain saturation. A method using light injection is experimentally demonstrated to reduce distortion and crosstalk. In a two-channel experiment with a data rate of 2.5Gbit/s, it is found that light injection can eliminate the BER floor due to distortion and crosstalk.

Wavelength-division-multiplexed (WDM) systems can utilise the vast bandwidth provided by a singlemode optical fibre. Semiconductor laser amplifiers (SLAs) are attractive devices for amplifying a number of multiplexed channels simultaneously. Compared with erbium-doped fibre amplifiers (EDFAs), with their small size, SLAs can be to integrated with other devices on the same substrate. In WDM applications of SLAs, when an SLA is gain-saturated, the gain of the SLA is pattern-dependent due to the long gain recovery time, and the gain of any channel is influenced by the intensity of other channels, which causes distortion and crosstalk [1 – 4]. Therefore, it is important to reduce the distortion and crosstalk caused by gain saturation in SLAs. The saturation output power of an SLA can be increased, and thus the distortion can be decreased [4], by using an MQW structure [5] or tapered waveguide structure [6]. The distortion and crosstalk can also be eliminated by using electronic compensation techniques [7].

The saturation output power is inversely proportional to the gain recovery time of the amplifier [8, 9]. The gain recovery time τ where τ_{nr} is the nonradiative (primarily Auger) recombination time, a is the stimulated emission rate constant, and S is the internal photon density in the SLA. The gain recovery time can be shortened by inducing more photon density in the amplifier. Recently, a three-wavelength configuration [8] was presented as a novel way of improving the characteristics of SLAs as all-optical processing elements. It was also found that the same configuration could improve the saturation characteristic by injection of pumping light [9] to increase the photon density. In this Letter, we demonstrate that the injection of pumping light can reduce the gain-saturation-induced distortion and crosstalk as well.

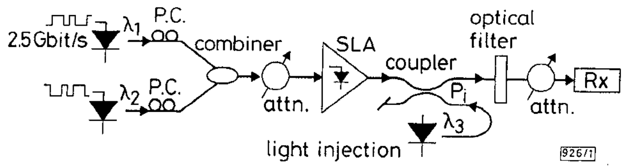

Fig. 1 *Schematic diagram of experimental setup to reduce SLA crosstalk by light injection*

3dB coupler after SLA may be replaced by optical circulator to reduce loss from 3dB to < 1dB

The experimental setup is shown in Fig. 1. Two semiconductor lasers are directly modulated at an OC48 data rate of 2.488Gbit/s. The wavelengths of these two lasers are λ_1 = 1544 and λ_2 = 1546nm. The signals from these two lasers are combined using a 3dB coupler, followed by a variable attenuator. The polarisations of the outputs of both lasers are controlled by polarisation controllers (PCs) to maximise the gain of the SLA. Light is injected in the counter-propagation direction through a 3dB coupler. The 3dB coupler after the SLA may be replaced by an optical circulator to reduce the loss from 3dB to < 1dB. The wavelength of the injected light is λ_3 = 1570nm at which the SLA has a small gain (SLA gain peak is ~1540nm) such that large optical power can be injected into the SLA without causing large gain reduction [9]. After the 3dB coupler, a tunable optical filter with full-width-half-maximum bandwidth of 0.6nm is used to select one of the two WDM channels. A variable optical attenuator is inserted before the receiver to measure bit-error-rate (BER) against received optical power.

In the experiment, the overall input optical power to the SLA was –12dBm in which each WDM channel had a power of –15dBm. The SLA gain at either channel was approximately the same. Fig. 2 shows BER against received optical power for various amounts of light injection. The amount of light injection at 1570nm was controlled by changing the bias current of the injection laser. A back-to-back BER measurement without an SLA was also conducted and is shown in Fig. 2 for comparison. The gain of the SLA was reduced with the increase in injected optical power [9]. Specifically, without light injection, the fibre-to-fibre gain of the SLA was 11.1dB; with –10dBm of light injection, the fibre-to-fibre gain was reduced to 10.3dB; with –7.5dBm of light injection, the fibre-to-fibre gain was reduced to 10.1dB; with –5dBm of light injection, the fibre-to-fibre gain was further reduced to 9.6dB.

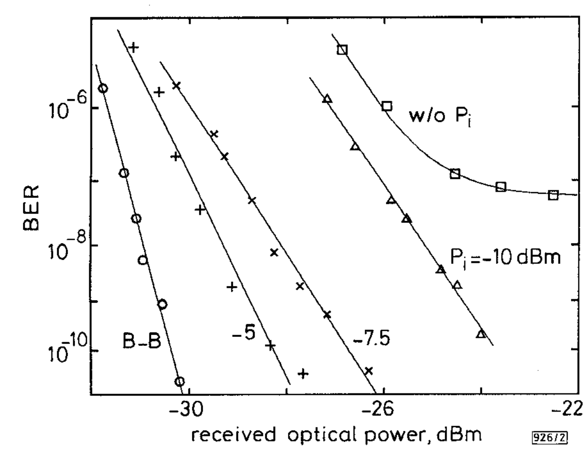

Fig. 2 *BER against received optical power with different injected optical power*

BER of back-to-back (B-B) connection is also shown for comparison

As shown in Fig. 2, the BER degraded with the reduction of injected light. Without light injection, SLA-induced distortion and crosstalk provided a BER floor of 10^{-7}. For a BER of 10^{-9}, the system sensitivities were –29.0, –27.4 and –24.5dB for injected power levels of –5, –7, –10dBm, respectively. The receiver sensitivity of the back-to-back connection was –30.5dBm. The 1.5dB degradation with –5dBm of light injection could be attributed to amplified spontaneous noise (ASE) of the SLA and residual distortion and crosstalk. Compared with a receiver sensitivity of –29.0 with –5dBm of injection power, as the injection power was reduced to –7.5 and –10dBm, we observed 1.6 and 4.5dB of reduction in receiver sensitivity, respectively.

In conclusion, from the experimental BER measurement of Fig. 2, we conclude that light injection is an effective method for reducing gain-saturation-induced distortion and crosstalk in SLAs.

30 September 1996

Electronics Letters Online No: 19961515

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Simplified method for the construction of an orthonormal base for CPFSK signals

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Indexing terms: Frequency shift keying, Modulation, Signal processing

The authors present a simplified method to derive a 2*M* dimensional orthonormal base for *M*-ary CPFSK signals based on the well-known Gram-Schmidt procedure. On the basis of this method, the simulated bit error performance of 4, 8 and 16-ary CPFSK modulation in additive white Gaussian noise channels is presented.

Introduction: The representation of CPFSK signals with the help of an orthonormal base provides us with the possibility of simulating them with very high accuracy during their transmission