ALL-OPTICAL REGENERATION and WAVELENGTH CONVERSION in an INTEGRATED SEMICONDUCTOR OPTICAL AMPLIFIER/DISTRIBUTED FEEDBACK LASER

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Introduction

The explosion of wavelength division multiplexed (WDM) systems in recent years has opened up a whole new dimension for increasing the flexibility of communications networks. It is likely that WDM systems will eventually move away from purely high capacity, point-to-point applications as they are now, towards offering a whole range of networking functions such as wavelength routing/switching and the ability to add or drop channels [1]. One function that is also likely to be required for WDM networking to blossom is the ability to all-optically transfer information from one wavelength of light to another in order to overcome possible wavelength contention at nodes of the network. Studies have shown that wavelength conversion in this manner can also aid network management and link restoration schemes. Many wavelength converters have been reported recently, including cross-gain and cross-phase modulation in SOAs, four wave mixing in SOAs, optical loop mirrors [2].

All-optical regeneration of data signals is also an issue. As a data signal propagates through the network, it inevitably suffers some form of degradation, chiefly through dispersion and accumulated noise from erbium doped fiber amplifiers. Regeneration is thus likely to be required to combat degradation, even in networks employing dispersion shifted fiber. At the high data rates envisaged, all-optical techniques are likely to be required to overcome the electronic bottleneck.

Here, for the first time, we demonstrate simultaneous all optical regeneration and wavelength conversion in an integrated semiconductor optical amplifier (SOA)/distributed feedback (DFB) laser after a 93km span of standard single mode fiber.

Device details

Figure 1a) illustrates a schematic of the SOA/laser which has been fabricated in InP/InGaAsP by Nortel Technology. It incorporates a 500μm SOA section and a 800μm DFB laser section with independent current biasing to both achievable via a split contact. The layer structure consists of an MQW active region with six 1% compressively strained InGaAsP wells and tensile-strained InGaAsP barriers surrounded by a two-step separate confinement heterostructure "GRIN" (graded refractive index) waveguide structure. The laser threshold is at 45mA and monomode emission at 1553.5nm is produced.

Under wavelength conversion, the optical input at λ_1 is injected into the DFB section of the device which then can suppress the DFB's output power via gain saturation. The SOA section causes further cross-gain mixing between the input wavelength and the output of the DFB, increasing the extinction ratio of the DFB. This device is operated in the reverse direction to our previous convertor [3], giving advantages in terms of eye opening and stability. The switching characteristics of the device under static conditions are shown in figure 1b), displaying a nonlinear transfer function.

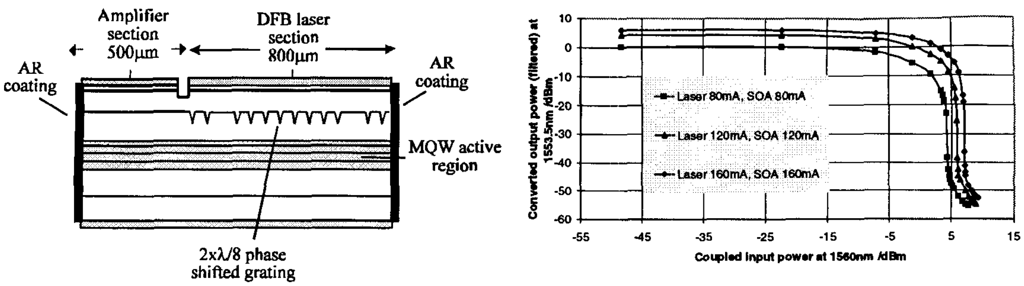

Figure 1: a) Schematic of the integrated SOA/DFB laser b) Static transfer characteristics of the device for various SOA and DFB currents. Optical injection at 1560nm is via the DFB laser facet, which emits at 1553.5nm.

The nonlinear transfer characteristic of the device can allow noise removal during wavelength conversion by presenting a threshold to switching. Any noise above this threshold power (>4dBm) will be removed due to a suppression during conversion to very low output powers (~-50dBm). It can also be seen that there is scope for extinction ratio improvements during conversion, leading to negative bit error rate penalties.

Simultaneous wavelength conversion and regeneration - experimental details

A CW laser source at 1548nm (λ_1) is externally modulated with a non-return to zero 2.488Gb/s pseudo random binary sequence via a $LiNbO_3$ Mach-Zehnder modulator, amplified using an erbium doped fiber amplifier, filtered to remove excess amplified spontaneous emission and injected into a 93km span of standard fiber (dispersion of 17ps/nm.km) at an average power of 6.25dBm. After transmission over the fiber span, the signal is re-amplified, filtered and polarisation controlled before injection into the SOA/DFB laser via a lensed fiber at a power of 8dBm. Owing to the device polarisation sensitivity, TE polarisation of the injected signal is chosen for optimum gain saturation performance. The currents to the SOA and DFB sections are 90mA each and the device is temperature controlled at 20°C. After filtering out of the input signal, the wavelength converted signal at 1553.5nm (λ_2) is detected on a receiver (with local clock recovery) and oscilloscope / bit error rate (BER) detector.

Results and discussion

Eye diagrams before the span, after the span and after wavelength conversion are shown in figure 2. It can be seen that the fiber span has a deleterious effect on the signal, due to the combination of dispersion and EDFA noise. After optimisation of the wavelength conversion process however, regeneration of the eye diagram is observed due to the noise removal properties of the device.

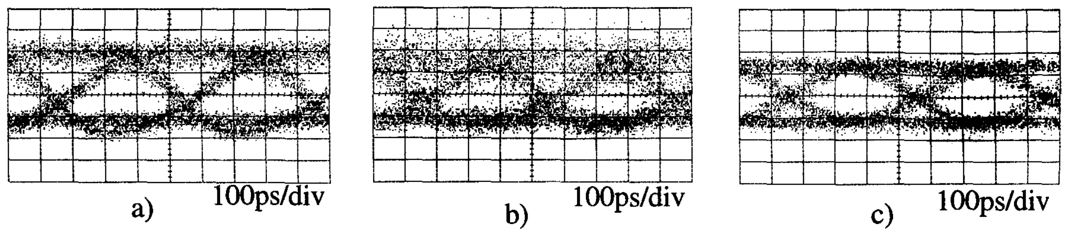

Figure 2: AC coupled eye diagrams of a) Initial 2.488Gb/s signal at 1548nm b) Input signal after 93km of standard fiber c) Wavelength converted signal at 1553.5nm showing regeneration

The corresponding BER curves for the above eye diagrams are shown in figure 3.

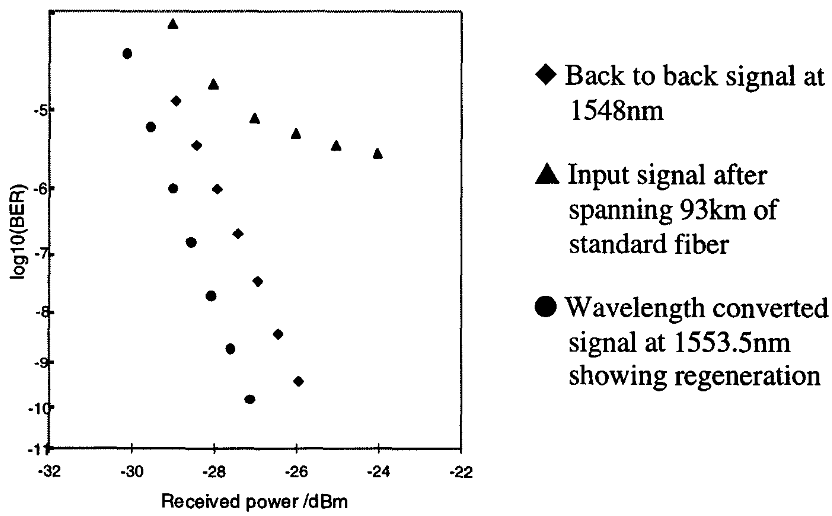

Figure 3: Bit error rate measurements showing regeneration from the wavelength conversion process

It can be seen clearly from figure 3 that the all-optical wavelength conversion process can support regeneration, totally removing the error floor produced from the fiber transmission, and actually creating a negative sensitivity penalty over the back-to-back input signal of -1.3dB.

Simultaneous all-optical wavelength conversion and regeneration has been achieved using one compact, integrated device at 2.488Gb/s. Simulation work has shown that the regenerative properties of many cascaded devices can allow transmission over >10000km of dispersion shifted fibre. These results as well as initial experiments showing 10Gb/s regeneration using this device will be presented at the conference

[1] CA Brackett, Journal of Lightwave Technology, **14**, no.6, June 1996, pp.936-941
[2] SJB Yoo, Journal of Lightwave Technology, **14**, No.6, June 1996, pp.955-965
[3] MFC Stephens et. al, Photonics Technology Letters, **10**, No.6, June 1998, pp.878-880