POLIS-based fast all-optical 2R regenerator

POLIS-based fast All-Optical 2R Regenerator

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Introduction

Optical communication systems are an important part of today's communications networks which have to support bandwidth hungry applications like video, online games and peer-to-peer applications. Like in most communication channels, signal degradation occurs in fiber optic cables, the most common transmission channel for optical communication systems. Even with the latest fiber technology featuring transmission losses as low as 0.2-0.3 dB [1] per kilometer, repeaters are required every 50-100 km [2]. Repeated all-optical amplification of the signal leads to an accumulation of noise caused by amplified spontaneous emission (ASE). This means that at the very least 2R regeneration is required to reshape the signal thereby improving the optical signal to noise ratio (OSNR). Various methods and devices are currently used to regenerate the optical signal. Here we report a study on a 2R regenerator based on semiconductor optical amplifiers (SOA) that is realized using the POLarization based Integration Scheme (POLIS). POLIS combines active and passive components on the same material, using polarization properties of compressively strained InGaAs/InP quantum wells [3]. This study is carried out using numerical simulations with well known SOA rate equations [4] and those suggested by M. Marell [5] for the polarization converters (PC). Unlike the previous study [5] we are concentrating on the ultrafast effects in the SOA with a view to extending the applicability of the device to network speeds of up to 40 Gbps.

Preliminaries

2R regenerators based on SOAs have been extensively studied in many configurations involving Mach-Zehnder interferometers [6, 7, 8]. This study follows the same trend using a similar concept, however the interference in this regenerator is between two orthogonal polarizations induced by polarization converters in the POLIS structure. Figure 1 shows

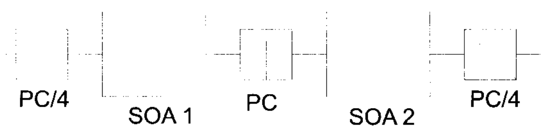

Figure 1: *2R regenerator*

a 2R regenerator with two partial polarization converters (PC/4) that split (on entry) or combine (on exit) the Transverse Electric (TE) and Transverse Magnetic (TM) polarizations. The full polarization converter (PC) switches the polarizations so that TE polarized light becomes TM polarized and vice-versa. The setup is such that, for signals that are not sufficiently strong (e.g. ASE noise contribution in a return-to-zero (RZ) digital system), the TE and TM polarizations will destructively interfere after traversing the regenerator due to the $\pi/2$ phase shift introduced by (PC/4) and (PC) converter. Stronger signals (the logical 1's) will induce a phase change due to self-phase modulation in the two SOAs so that they are not 180° out of phase at the combining partial polarization converter.

Results

The transfer function of the setup mentioned above has been studied by M. Marell [5] and it agrees with the well known transfer function necessary for 2R regeneration.

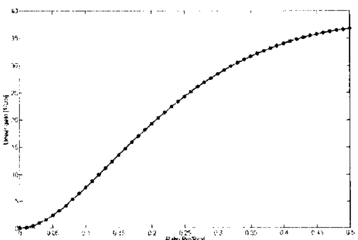

Figure 2: *2R regenerator transfer function*

Ultrafast nonlinear processes of the SOA have been studied using differential equations suggested by Mecozzi and Mørk [4]

$$\begin{aligned}
\frac{dh_N}{dt} &= -\frac{h_N}{\tau_s} - \frac{1}{S_s\tau_s}[G(t,z)-1]S(t,0) + \frac{g_0(z)}{\tau_s} \\
\frac{dh_{CH}}{dt} &= -\frac{h_{CH}}{\tau_{CH}} - \frac{\varepsilon_{CH}}{\tau_{CH}}[G(t,z)-1]S(t,0) \\
\frac{dh_{SHB}}{dt} &= -\frac{h_{SHB}}{\tau_{SHB}} - \frac{\varepsilon_{SHB}}{\tau_{SHB}}[G(t,z)-1]S(t,0) - \frac{dh_{CH}}{dt} - \frac{dh_N}{dt}
\end{aligned} \tag{1}$$

where ε_{SHB} and ε_{CH} are the nonlinear compression factors due to spectral hole burning (SHB) and carrier heating (CH) respectively. τ_s, τ_{CH} and $\tau_{SHB}$are the carrier lifetime, temperature relaxation time and carrier-carrier scattering times. h_N, h_{CH}, h_{SHB} are the modal gain contributions of carrier density, CH and SHB respectively.
The results show that there is sufficient phase change and recovery of the saturated gain to support speeds of up to 40 Gbps for miliwatt (mW) strength optical signals that are used in most optical communication systems.
The next step is to simulate the behavior of the optical pulses through the whole system and to calculate the improved OSNR and extinction ratio of a sequence of optical pulses.

Conclusion

The high speed operation of a 2R regenerator capable of operating in WDM systems at 40 Gbps is being studied. This regenerator occupies a smaller chip area than most 2R regenerators because of the use of a cascaded design as opposed to the Mach-Zehnder interferometer design which uses two arms.