Regeneration and Cascadability Assessment of a New Passive 2R Regenerator Based on a Dual-Stage Saturable Absorber gate

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Abstract

We report on the regenerative properties and on the cascadability assessment of a passive 2R regenerator based on a dual-stage microcavity saturable absorber gate for low and high levels regeneration.

Introduction

Optical regeneration could be one of the key devices for long haul transmission systems provided that it is compatible with a WDM operation. The saturable absorber (SA) in a microcavity is particularly attractive for its passive operation and its wideband behaviour. The quite good compatibility of this component with a WDM operation was notably demonstrated in [1]. Nevertheless this structure mainly enhances the extinction ratio without having an impact on the amplitude noise reduction on high power levels [2], and a complementary function is necessary to have a complete 2R regeneration. For this purpose, the previously reported fibre-based technique [3] for high power level regeneration would be difficult to implement in a WDM system, while the SOA-based technique is limited by the gain recovery time of the SOA [4]. In [5], a new structure was proposed based on the same technology than the classical SA in a microcavity but by modifying the cavity parameters, a dynamical power limiter was obtained.

In this paper, we report for the first time on the regenerative properties of a 2R regenerator based on the cascade of two saturable absorber vertical microcavity devices, one that treats the low power levels (SA.0) and one that treats the high power levels (SA.1).

Structure

The SA.0 efficiency for optical regeneration has been largely demonstrated [1-4], and the present paper is focused on the assessment of the SA.1. The SA.0 used in this paper is the module described in [1] and won't be described in this paper. The SA.1 was composed of 7x(InGaAs/InAlAs) multi-quantum wells (QWs), grown by metal-organic vapor-phase epitaxy upon an InP substrate and contained in a microcavity. The QWs are suitably located at the antinode of the intracavity intensity. In order to reduce the carrier lifetime, the QWs were irradiated by 12MeV-Ni6$^+$ ions with a dose of $4.10^{11}cm^{-2}$. 10 MHz pump-probe measurements at 1548 nm showed a response time of 3 ps. The back mirror was made by deposition of silver layer (with a calculated reflectivity of 0.945), while three pairs of (ZnS/YF_3:λ/4:λ/4) were deposited as a top mirror with 0.92 reflectivity. The sample was mounted on a Si substrate by Au-In bonding, to make easier heat dissipation and limit thermo-optics effects. The reflected power with wavelength is represented on the Figure 1, showing a resonance wavelength of 1551 nm and a 3 dB bandwidth of 14 nm.

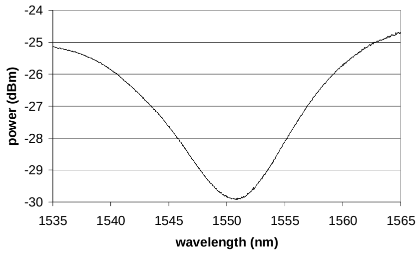

Figure 1: Reflectivity spectrum.

A 42.6 Gbit/s pump probe experiment was performed on this structure. The pump signal was a standard RZ 33 % signal with a 2^{31}-1 bits PRBS sequence. The probe was a continuous laser at the resonance wavelength. The signal was injected onto the non linear mirror through an optical circulator. The probe signal is modulated by the pump as a result of the absorption saturation and of the resonating cavity. The contrast, defined as the ratio of the reflected signals from a high and a low power levels has been measured versus the input power (Figure 2).

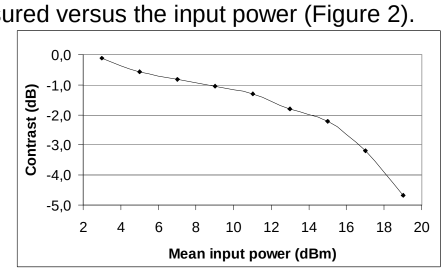

Figure 2: Contrast measurement at 42.6 Gbit/s.

The data in Figure 2 show a negative contrast, as expected for a limiting power function. We measured a maximum absolute contrast of 4.7 dB for an input mean power of 19 dBm; as far as the role of the component is to reduce amplitude noise on high power levels, the required contrast depends on the place of the regenerator in the link.

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As far as the SA.0 is concerned, in this case the contrast is positive namely the reflectivity of high power levels is higher than the reflectivity of low power levels, leading to an improvement of the extension ratio and an attenuation of noise.

Regenerator architecture and system experiment

In order to perform a complete 2R regeneration based on saturable absorber micro-cavities, SA.0 and SA.1 have been included together in a recirculating loop.

The loop was composed of a short portion (10 km) of dispersion shifted fibre (DSF) in order to assess the cascadability of the regenerator independently from the propagation effects.

The experimental setup is shown on Fig. 3. The transmitter (Tx) produces an RZ (33 %) optical signal modulated at 42.6 Gbit/s with a 2^{31}-1 bits PRBS at 1550 nm.

Erbium doped fibre amplifiers (EDFA) compensated for the losses. An optical filter limits the ASE accumulation over the full amplification band.

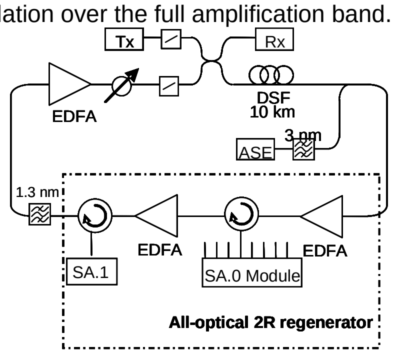

Figure 3: Experimental setup.

The SA.0 module was the one used in [1]. The signal was injected into the SA thanks to optical circulators (OC). Input power in front of the SA.0 was 9 dBm.

ASE noise was added into the loop in order to assess its ability to reduce it. With noise, the OSNR was equal to 18 dB (over 1 nm) after one cascade without regeneration and a Bit Error Rate (BER) of 10^{-8} was obtained after 4 cascades.

Results

In order to assess the ability of SA.1 to reduce the amplitude noise, we observed the eye diagram after 10 cascades by varying the power at its input.

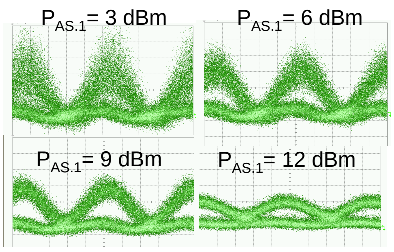

Figure 4: Eye diagrams after 10 cascades for different input power onto the SA.1.

The eye diagrams for SA.1 input power of 3, 6, 9 and 12 dBm depicted on Figure 4 clearly show that amplitude noise on high power levels is significantly reduced with an input power of 9 and 12 dBm.

Finally an optimum operation was obtained with an input power of 9 dBm, allowing a transmission over 10 cascades with a BER of 10^{-8}. We thus demonstrate an increase of the number of cascades of a factor 2,5 and the possibility to cascade 10 times the regenerator. Figure 5 shows the eye diagrams after 10 cascades, with and without regenerator showing the high power noise reduction.

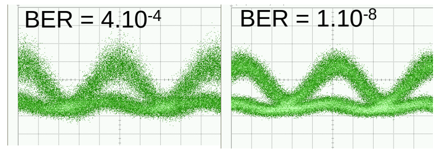

Figure 5: Eye diagrams after 10 cascades with and without regenerator.

However, some efforts still have to be made on the SA.1 and on the regenerator architecture as it was found impossible to cascade more than 10 times the regenerator properly. Some spectral deformations may be the cause of the limitation. The saturation of the absorption indeed gives rise to a dip in the reflectivity spectrum; hence the signal spectrum is distorted when transmitted through the device, in a cumulative way. We should be able to compensate for this effect thanks to a gain equalizer filter.

Conclusion

In this paper we demonstrate for the first time the regenerative properties of a new 2R regenerator based on the cascade of 2 passive saturable absorbers based on the same technology. A classical SA is completed with a new device allowing a regeneration on high powers. A contrast of 4.7 dB was measured with this structure at 42.6 Gbit/s. The regeneration on high power was demonstrated for the first time through a recirculating loop experiment allowing 10 cascades in the regenerator for a BER of 10^{-8} (a 2.5 increase in the number of cascades). Some efforts are still needed on this promising regenerator in order to be able to cascade it more than 10 times.

Acknowledgement

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