Cascadability Assessment of an All Optical 3R Regenerator based on Synchronous Modulation in a Saturable Absorber and Optical Clock Recovery

1 : Laboratoire d’Optronique, CNRS UMR FOTON 6082
2 : LPN-CNRS, Route de Nozay, F-91460 Marcoussis, France, le@enssat.fr
3 : Alcatel Thales III-V Lab, Route Départementale 128, 91767 Palaiseau, France, guanghua.duan@3-5lab.fr

Abstract We report on the cascadability assessment of 3R regeneration based on optical synchronous modulation using cross saturation absorption in a quantum-well microcavity driven optically by the recovered clock from a self-pulsating laser device.

Introduction
An all optical regenerator could be one of the key devices for long haul transmission systems. Previously, the transmission quality enhancement of optical signal using optical 2R regenerator and in-line synchronous modulation with optoelectronic clock recovery has been demonstrated [1,2].

In this paper, we report for the first time the cascadability assessment of a 3R regeneration device based on a 2R regenerator and all optical synchronous modulation. The 2R regenerator is based on the combination of Self-Phase Modulation (SPM) in an optical fibre and Saturation Absorption (SA) in a quantum-well microcavity. The all optical synchronous modulation is achieved by launching into the SA the optical clock obtained from an all optical clock recovery device using Self-Pulsating (SP) semiconductor lasers based on bulk and quantum-dot (QD) structures.

Regenerator architecture
Figure 1.a) presents the 2R regenerator architecture. The passive 2R regenerator is thus made of two stages: the first pulse compression stage comprising a nonlinear fibre (NLF) followed by an optical band-pass filter (OF) for equalisation of ‘mark’ levels, and the second stage made of the SA module for attenuation of the ‘space’ levels [3]. The pulse compression stage consists of a 1 km span of Dispersion Shifted Fibre (DSF) with 0.1 ps.nm \(^{-1}\).km \(^{-1}\) dispersion and a 1 km span of standard Non-Zero-DSF with 4.5 ps.nm \(^{-1}\).km \(^{-1}\) dispersion at 1550 nm. This stage requires an EDFA with 18 dBm output power. An optical circulator (OC) allows injecting and recovering data signal in an 8 channel SA module (one channel is used in this experiment). The packaged and pig-tailed SA, realised by partners of the French research program ASTERIX, allows a compact and low cost technique for WDM regeneration [4].

The optical clock recovery (OCR) part is implemented to introduce the synchronous modulation. Our OCR consists of a double stage Self Pulsating laser combination from Alcatel Thales III-V lab (figure 1.b), previously described in [5]. The first stage is a Distributed Bragg Reflector (DBR) laser containing a polarization insensitive bulk active layer and the second stage is a Self-Pulsating Quantum-Dot Fabry-Perot Laser (QD-SP). The first SP laser produces an optical clock at 1548 nm which is precisely synchronized to the optical data signal at the input at 42.6 GHz. The great advantage of this laser is its polarization insensitivity, in spite of its insufficient jitter filtering capability. The second stage works at 1575 nm and provides a high purity clock thanks to its intrinsic jitter filtering effect [6]. The association of these two lasers yields a polarization insensitive high performance OCR part.

The optical clock is then injected to the transmission line and launched into the SA. The relative delay between incoming data and recovered clock can be controlled by an optical delay line (ODL). The optical synchronous modulation is obtained by cross absorption modulation in the SA. The optical clock is filtered out of the transmission line by the second OF.

Fig 1: Schematic of regenerator architecture (a), and optical clock recovery part (b).

Cascadability achievement experiment
The re-circulating loop set-up is shown in the figure 2. The transmitter produces an RZ (33 %) optical signal modulated at 42.6 Gbit/s with a PRBS sequence length of \(2^{31}-1\).

The transmission loop consists of 100 km of TrueWave Reduced Slope (TW-RS) fibre with a chromatic dispersion of 4.5 ps.nm \(^{-1}\).km \(^{-1}\) at 1550 nm.
Distributed Raman amplification is achieved by backward pumping the transmission fibre; the on/off Raman gain for each span is approximately 10dB. The chromatic dispersion is compensated just before the regenerator by an enhanced high slope (EHS) Dispersion Compensating Fibre (DCF) module to restore the pulse duration.

Figure 2: Schematic of the re-circulation loop experiment. The 100 km loop consists of two spans of 50 km TWRS fibre, DCF and an Optical 3R regenerator.

Results

Figure 3 shows the measured Bit Error Rate (BER) as a function of transmission distance with and without synchronous modulation. Without the synchronous modulation, using only 2R regeneration, the BER grows rapidly due to timing jitter. However, BER of $10^{-8}$ is attainable over 8000 km corresponding to a factor 10 of transmission distance enhancement as compared to the case without regeneration.

When the optical synchronous modulation is applied, timing jitter is reduced and the transmission distance is considerably enhanced (18000 km with a BER of $10^{-8}$ corresponding to a transmission distance enhancement factor of 22.5).

Conclusions

Thanks to an experimental cascadability assessment study, we have shown for the first time the efficiency of an all optical synchronous modulation regenerator using cross absorption modulation in a SA microcavity, and a very compact clock recovery. We show a considerable improvement in propagation distance at 42.6 Gbit/s. A significant margin on receiver decision time is obtained with this modulation technique showing evidence of a retiming effect. Finally, this all optical signal regeneration technique could be improved in the future by using a newly designed SA microcavity for better “mark” regeneration, which could avoid using the NLF fiber.

References

[1] G. Raybon, OFC (2003), TuH1
[6] J. Renaudier et al, ECOC (2005), PDTh4.3.4