Impact of Transient Response of Optical Amplifiers Operating with Burst Traffic

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***Abstract* — In this paper, the transience of optical amplifiers (Raman and EDFA) at 10 Gbit/s burst transmission is assessed. For a set of two saturated EDFA over 50 km of standard single mode fiber (SSMF), the transience was clearly observable in the packet envelope but almost negligible for Raman amplifiers. Quantitative results were also obtained for Raman amplification over two spans 29425 m and 28816 m of SSMF. The results pointed out that Raman amplification is more suitable for operating in bursty traffic than EDFA.**

I. INTRODUCTION

Optical Burst Switching (OBS) has been proposed as a technique to overcome issues related to wavelength division multiplexing (WDM) deployment (lack of fine granularity in wavelength routing and electronic speed bottleneck in SONET/SDH [1]. In such networks, the data packets are assembled into bursts on the WDM channel and transported across the optical core to the destination. An inherent aspect of this methodology is the existence of long inter-burst idle intervals (from nanoseconds to seconds). However, this technology is in its early stages and several problems have to be surpassed, namely the amplifier transients. The Erbium doped fibre amplifier (EDFA) transients arise due to two factors: (i) they usually work in deep saturation and (ii) the long upper state lifetime of Erbium ions (~ 10 ms) implies that there is a pool of inverted carriers shared by the channels [2]. It was also demonstrated that the EDFA transience is cumulative which can jeopardize seriously the clock and data recovery at the receiver [3]. The used strategies to deal with the EDFA transience fall into two categories: electric approach, as automatic gain control [4] and optical approaches, as optical feedback loops [5]. The automatic gain clamping technique failed when applied to burst traffic because in 10 Gbit/s and 500 byte packets the packet duration is faster than techniques response. However, others mitigation approaches have been proposed, such as the use of EDF with enhanced active Erbium area [6]. This underlying idea is to pursue intrinsically low transience by decreasing the gain excursion.

The Raman transients are expected to be less severe because they usually work in unsaturated regime and the upper state lifetimes are very short (~3-6 fs) and for these reasons, the study of the Raman transience in burst traffic is in an early stage [7]. However, some work has been reported in order to estimate the performance of bursty optical systems with Raman amplifiers [8].

The paper is organized in the following way: in section II the transience of EDFA versus Raman is qualitatively assessed for a span of 50 km of SSMF, by the observation of the burst patterns on an oscilloscope. In section III, BER measurements against optical power at the receiver are drawn for two span of SSMF with Raman amplification and a power penalty of 2.42 dB was obtained.

II. QUALITATIVE ASSESSMENT OF AMPLIFIERS TRANSIENTS (EDFA AND RAMAN)

This experiment aims to assess the impact of EDFA and Raman transients for a 1x10 Gbit/s. The experimental setup consists of a laser peaking at 1550 nm, followed by an electro-absorption external modulator driven at 10 Gbit/s. The propagation occurs over 50 km SSMF fiber. The Raman scheme is based in a counter-propagation Raman amplification module from Keyopys, model KPS-RFL-MW2-1430/1460-15/15-FA, with 3 pump lasers peaking at 1428 nm, 1445 nm, 1464 nm and a total optical power of 1W. The EDFA amplification scheme used two EDFA spans, the first was set for a low pre-amplification and the second with more power, both in saturation.

For this system, the signal at the receiver was directly detected by a digital oscilloscope, with optical head (Agilent 86100A).

For these tests a composite signal was constructed with the fowling packet.

128 bits (0,1,0...)	10 bits "0"	3814 bits "PRBS"	11168 bits "0"

The observed results in the oscilloscope for the back-to-back and receiver patterns for EDFA and Raman are displayed in Fig.1 (a) and (b) and (c), respectively.

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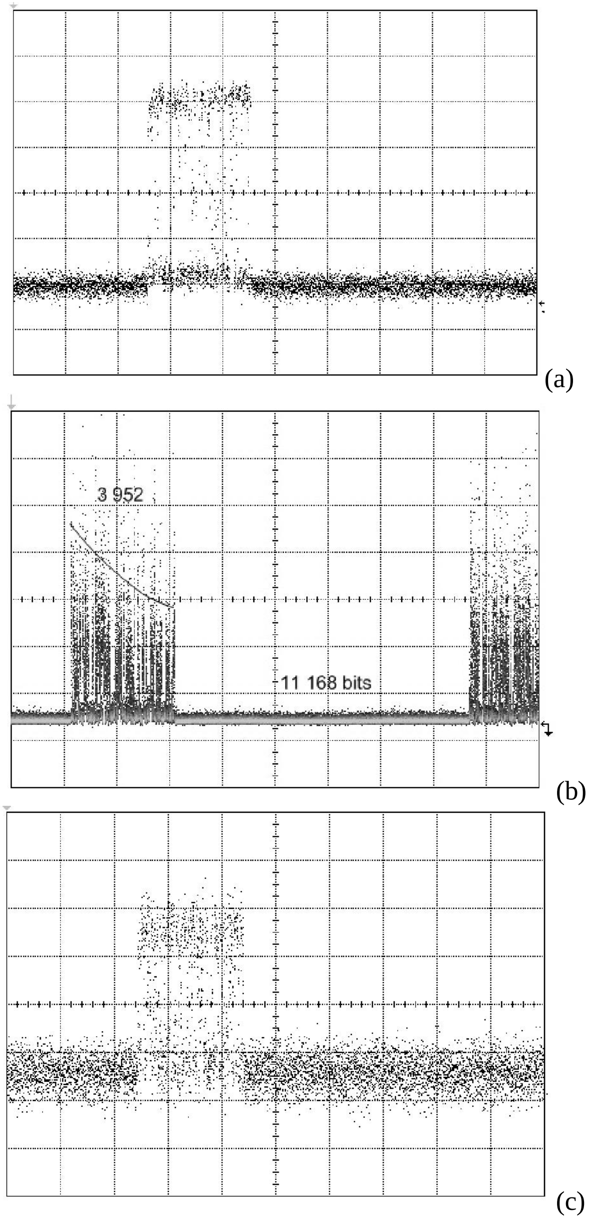

Fig. 1 Bit sequence at: (a) back to back. (b) the receiver for double EDFA amplification, (c) the receiver for Raman amplification. The vertical scale is arbitrary and the horizontal scale is 200ns/div.

By looking at those results, we notice that the transience due to EDFA amplification in the decaying of the packet envelope. Those results were expectable because the EDFA are saturated. Regarding the Raman amplification, the effect of transience is not observable. Those results point out that Raman amplification is more suitable for burst traffic.

III. IMPACT ON THE RECEIVER PERFORMANCE

In this experiment, the effect of the Raman amplification on the performance of an optical burst is assessed quantitatively.

The experiment follows the setup depicted in Fig. 2. The signal emitted by the tuneable laser (NetTest Tunics) is centred at 1546.71 nm with input power equal to 10 dBm. The receiver is composed by a packet receiver, an error detector (Anritsu MP1704A), a demultiplexer (Anritsu MP1802A) and an oscilloscope (Agilent Infinium 86100A). The bit data are generated at 9.95328 GHz.

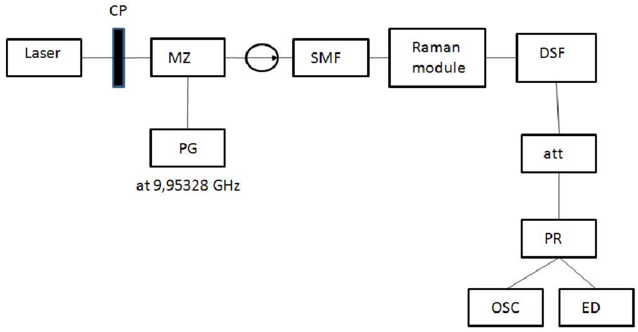

Fig. 2- Setup of the implemented experiment.

A packet with a 192 bits header (Preamble: 64, Frame: 64 and Sequence field size: 64), a 8840 bits payload and a gap length with 524288 bits (that corresponds to approximately to 53 μs) is generated. The transmission medium is a SSMF fiber - two different spans were used with 29425 m (fiber1) and 28816 m (fiber 2) respectively. The Raman module (Fitel HPU-CL12W14D-00077) was used with the 14 lasers on maximum power (1.2 W) and 11268 m a SDF fiber was included to prevent the penalties dues to chromatic dispersion. The patterns of the packet and eye diagram visualized on the oscilloscope at the end of transmitter and the receiver for each fibre are depicted in Fig. 3. To obtain the BER curves as a function of the power at the receiver an attenuator (Agilent 8156A) was added to the experimental scheme. The power penalties obtained for both fibers are approximately equal to 2.42 dB, as displayed in Fig. 4.

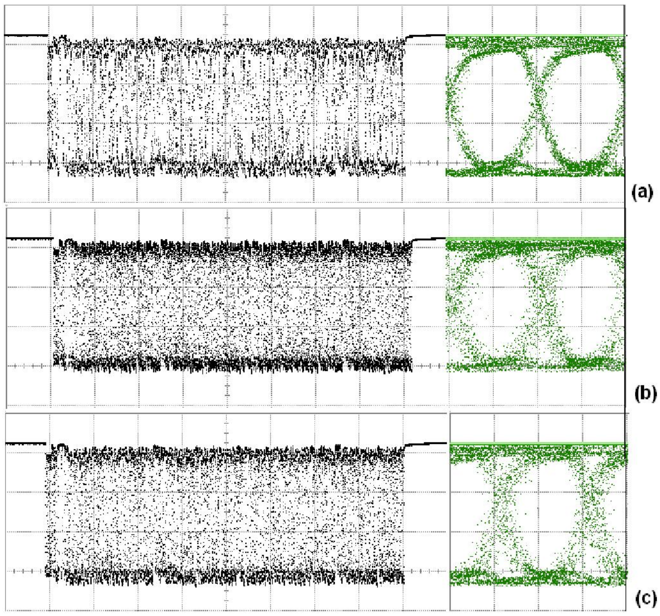

Fig. 3- Pattern and eye diagram at the end of the: (a) Tx, (b) Rx with fiber 1 and (c) Rx with fiber 2.

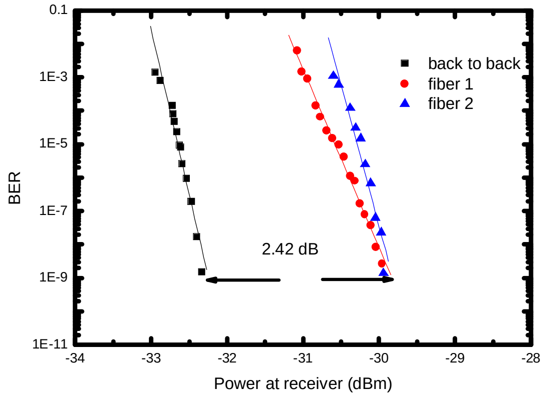

Fig. 4- BER curves for back to back, fiber 1 and fiber as a function of the power at receiver.

IV. CONCLUSIONS

We appraise both qualitatively and quantitatively the effect of amplification on burst traffic at 10 Gbit/s. The impact of EDFA was observed as a decaying packet envelope. The effect on Raman amplifiers is negligible. The BER measurements also demonstrated the suitability of the latter for burst mode transmission.

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