

# TRANSIENT CONTROL BY FREE ASE LIGHT RE-CIRCULATION IN EDFA BASED WDM RING NETWORKS

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**Abstract:** We demonstrate that a free ASE light re-circulation in EDFA based WDM ring networks provides an effective gain clamping technique. Proper network and amplifier design ensure signal power overshoots lower than 2.5 dB under 23/24 WDM channels add-drop operations.

## 1. INTRODUCTION

Low cost and effective amplifier power transient controls are becoming essential for future WDM metro-core network development. Although new amplification technologies, such as Raman [1] and semiconductor optical amplifiers [2] can provide remarkable performances in terms of gain bandwidth and flexibility, standard EDFAs are still the most attractive solution as the best trade-off between cost and performances. When EDFAs are used in add/drop networks, or in presence of traffic bursts, signal power transients due to the variable input signal load, can cause serious performance degradation, therefore gain control techniques must be used.

In WDM ring networks, in which EDFAs are used to compensate the losses of both fiber spans and network elements, closed optical paths can be formed, giving rise to uncontrolled lasing oscillations which can impair network performances under WDM channels add-drop operations [3]. Although it has been previously shown that closed cycle lasing can be made stable, and used to stabilize re-configurable WDM networks [4], no transient effects and network performance analysis has been reported, to the best of our knowledge.

In this paper we experimentally demonstrate an effective gain clamping technique for EDFA based WDM ring networks, which is based on free amplified spontaneous emission (ASE) light re-circulation along the ring. We show that proper network and amplifier design, can make the system robust to WDM

channels add-drop operations, providing, at the same time, a cost effective signal power transients control and acceptable optical signal to noise ratio (OSNR) performances.

## 2. EXPERIMENTAL SET-UP

Fig. 1 shows the experimental set-up we have used to reproduce a worst case scenario in term of transient effects. Seven, high power, 100 GHz spaced DFB lasers (from 1552.5 nm to 1557.6 nm) are multiplexed and switched on and off at 100 Hz by an acousto-optic modulator, before being combined with a probe signal at 1551.7 nm (the modulation period is 5 ms, much longer than the network round trip time, which is about 950  $\mu$ s). Note that in order to reproduce adding and dropping of 23/24 channels, the power/channel of the seven loading signals is always chosen about 5 dB higher than the probe power ( $10\log_{10}(23/7)=5.16$ ).

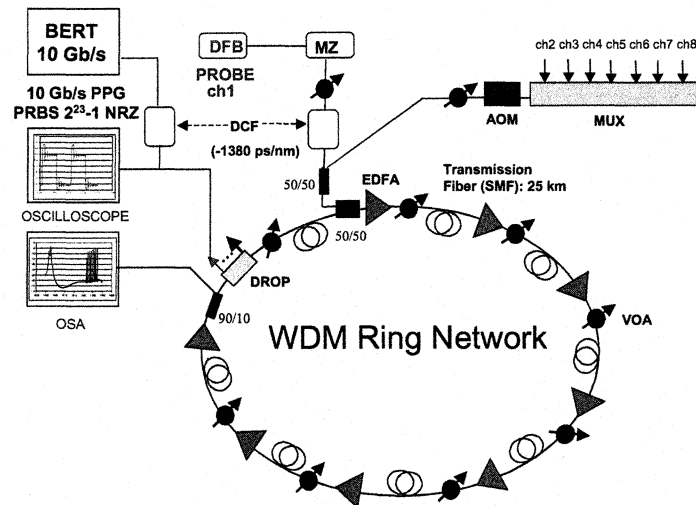


Fig. 1: Experimental set-up representing a worst case scenario.

All WDM signals are then inserted into the ring, at the first EDFA input, and then propagated along the network before being extracted at the last EDFA output, through a fixed 8 channels add-drop multiplexer which leaves the ASE light to freely circulate in the ring. All EDFAs in the network are operated at constant pump power (100 mW at 980 nm). The set-up shown in Fig. 1 allows us to measure the output spectrum, optical signal to noise ratio (OSNR), the probe power

transients induced by add-drop operations and the probe bit-error-rate performances at 10 Gb/s. Note that two dispersion compensating fiber spools (-1380 ps/nm) are introduced respectively at the transmitter and receiver side, to compensate exactly for the accumulated chromatic dispersion. Variable optical attenuators (VOA) are used in each fiber span (25 km of standard SMF) and at the transmitter side in order to investigate network performances in different operation conditions such as varying the input power per channel and the span losses.

### 3. WDM RING NETWORK PERFORMANCES

We have first investigated the probe power transient behaviour (see Fig. 2) at the last EDFA output, under 23/24 WDM channels add-drop operations at the first EDFA input; the input probe power is -17 dBm and the span loss is 20 dB, high enough to ensure stable gain peaking at around 1532 nm, that is far enough from the WDM signal band (from 1542 nm to 1561 nm with 24, 100 GHz spaced channels).

Note that, for a given EDFA structure and input power per channel, the span loss must be optimized in order to ensure the best compromise between good OSNR performances and lasing stability at around 1532 nm, under full WDM channels add-drop operations.

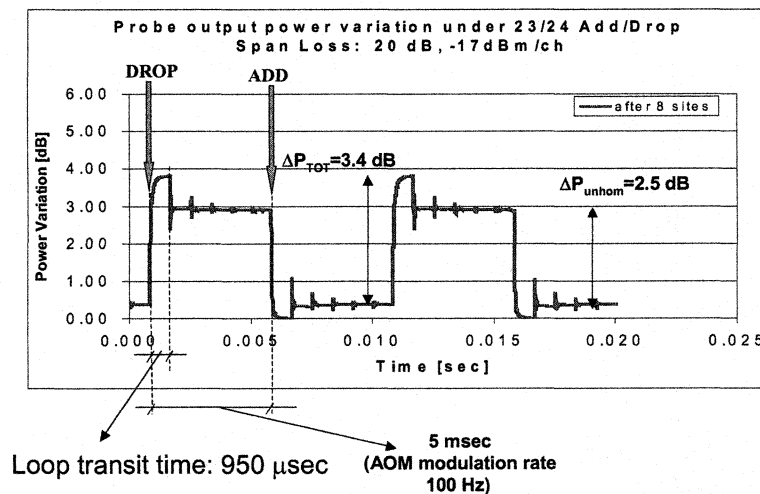


Fig. 2: Transient behaviour at the last EDFA output induced by 23/24 WDM channels add-drop at the first EDFA input.

From Fig. 2 we can notice a maximum probe power overshoot ( $\Delta P_{TOT}$ ) of about 3.5 dB, which is very small if compared with the strong power transient which would be expected in such a long EDFA chain without any gain control ( $\approx 13$  dB). Also note that after each loop transit time ( $\approx 950$   $\mu$ s) the lasing light, re-circulating along the ring, clamps the gain with typical probe power transients induced by the lasing relaxation oscillations. The clamping mechanism, provided by the ASE light re-circulation, is only partially effective and the steady-state probe power level remains about 2.5 dB above the steady-state condition with full network load ( $\Delta P_{UN-HOM}$ ); this is due to spectral hole burning and un-homogeneous gain.

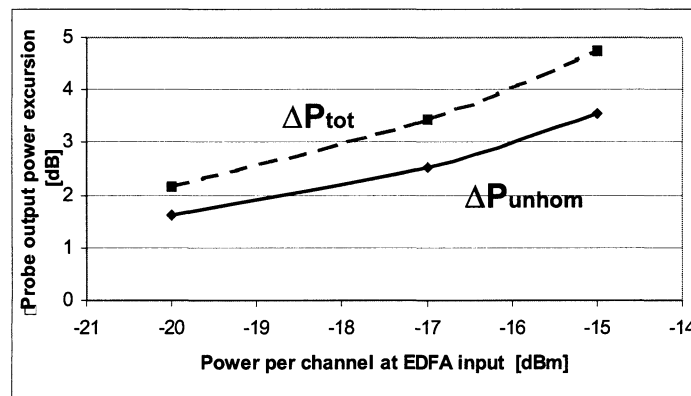


Fig. 3: Probe power excursion at the last EDFA output induced by 23/24 WDM channels add and drop versus input signal power per channel.

We have also investigated the probe power transients by varying the input signal power per channel.

Fig. 3 clearly shows that both maximum overshoot  $\Delta P_{TOT}$  and steady-state power difference  $\Delta P_{UN-HOM}$ , grow with the input power per channel. This is due to the fact that the more the lasing light is predominant, compared to the total signal power, the more the clamping mechanism, provided by ASE light re-circulation, is effective.

The probe output OSNR is greater than 24 dB (resolution bandwidth: 0.1 nm) and its maximum OSNR variation, induced by polarization dependent effects, has been measured to be less than about 0.7 dB. Also the probe relative intensity noise (RIN) has been measured and compared with open and closed ring, at the same OSNR value: no penalties have been observed due to RIN transfer from laser light to signals.

However, in order to exclude all possible potential transmission penalties, related to both probe power transients and noise transfer from lasing light to WDM channels, we have performed BER measurement at 10 Gb/s.

The probe signal has been externally modulated at 10 Gb/s (PRBS 223-1, NRZ format) and BER measurements versus OSNR have been performed under WDM channels add-drop operations.

Fig. 4 shows that no BER penalties have been observed with respect to back-to-back conditions (receiver characterization by noise loading).

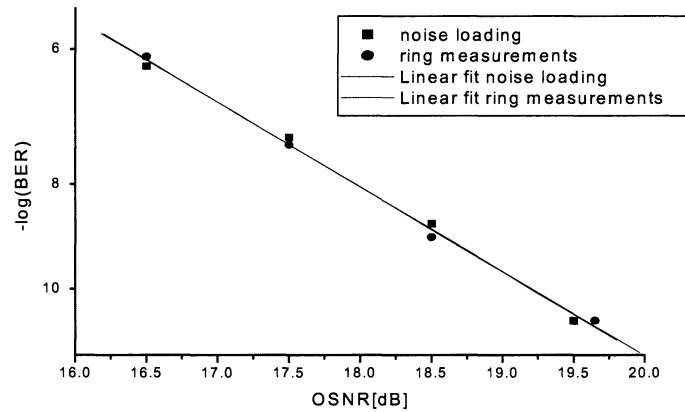


Fig. 3: BER versus OSNR with noise loading and with ASE light recirculation.

#### 4. CONCLUSIONS

We have presented and experimentally demonstrated an effective gain clamping technique, based on free ASE light re-circulation, in EDFA based WDM ring networks for metro applications.

Experimental results confirm that a proper EDFA and network design ensure robustness to add-drop operations and acceptable OSNR performances, without any transmission penalty related to the presence of ASE light re-circulation.

#### ACKNOWLEDGMENTS

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