Optical Test Platform for High Bit Rate DWDM Systems

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Abstract

The purpose of this paper is to present an optical test platform for high bit rate DWDM systems. The developed platform is transparent and independent of the format of the optical signals, number of WDM channels and transmission ratios. It enables the laboratory simulation of real systems with multi-wavelength and high bit rates optical networks.

I. INTRODUCTION

Since the introduction of Erbium-Doped Fiber Amplifiers (EDFA), the capacity of long-haul transmission systems has greatly increased. The success of the development of such systems relies on the capacity to accurately determine the system's end-to-end performance.

When is required to transmit an optical signal over long distances, several kilometres and optical amplifiers are needed. These circumstances lead to the degradation of quality of the signal received and the consequent increase in the bit error ratio.

The main causes for the degradation of the signal are the attenuation and dispersion of the fiber and the non-linear effects such as self-phase-modulation, stimulated Raman scattering and the stimulated Brillouin scattering which are more notorious when the fiber length used and the average optical power are high.

In WDM systems, the crosstalk, the non-linear effects such as four wave mixing and cross phase modulation are also responsible for the degradation of the signal.

Circulating loop techniques (also called Optical Loop) can provide an experimental platform suitable for studding a broad range of these transmission phenomena for EDFA based transmission systems [1].

Initially the Optical Loop tests were used to characterize pulse propagation in early MM and SM fiber systems. A recent renewed interest in circulating loop testing has been fueled by R&D of OC-192 rate (9.95328 Gb/s) transmission systems, dispersion compensating systems (soliton), EDFA based systems and WDM systems.

The advantage of loop experiments over a test bed based on several optical amplifiers and hundred of kilometers of fiber is obvious from the practical and economic point of view.

In this way, with the optical loop, it's intended to create a high distance emulator with characteristics of an equivalent real system. The system must be transparent and independent of the format of the signals, number of channels in WDM or transmissions ratios.

II. OPTICAL TEST PLATFORM

The implemented optical test platform is illustrated in figure 1. The developed platform is based into four main functional blocks: a DWDM emitter, an optical loop, an add-drop device and an optical receiver.

A. *DWDM Emitter*

The DWDM emitter is based on three lasers coupled with a star coupler. A Mach-Zehnder type electrooptic modulator does the modulation externally. A polarizer is present before the Mach-Zehnder to maximize the extinction ratio. The modulation is driven by a PRBS generator capable of generate data sequences at a maximum bit rate of 3 Gbit/s in NRZ format.

B. Optical Loop

The second block is the optical loop used to emulate long transmission distances. The loop is controlled by two Mach-Zehnders preceded by two polarizers that are used as optical switches, controlled externally by a controller device specially designed for the effect.

The controller device is based on digital control for the timing and analogical control for the offset and amplitude of the optical switches. It produces three control signals, VCtrl1, VCtrl2 and Trigger. The VCtrl2 signal is a logical inversion of the VCtrl1. The generic control diagram of these three signals is shown in figure 2. The first signal (VCtrl1) represents the control of the first Mach-Zehnder responsible for the signal injection inside the loop. The duration of the 'On' state is the same or less than the circulation period inside the loop to avoid overlap with adjacent laps.

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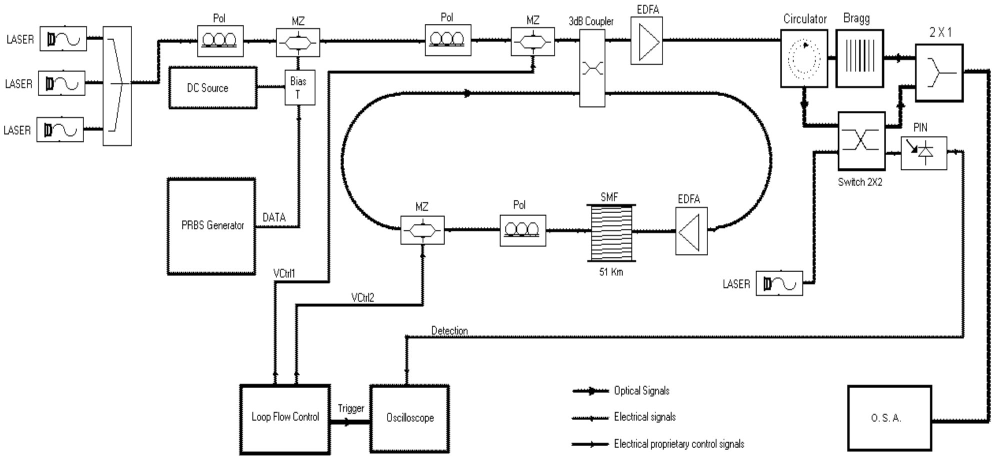

Fig. 1 - Schematic diagram of the experimental setup.

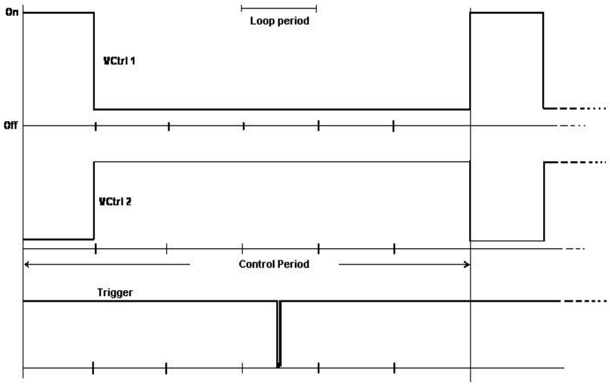

Fig. 2 – Temporal control diagram

The second Mach-Zehnder is in the ‘On’ state during the time the signal flows inside the loop, and goes to ‘Off’ state when a new signal is inserted in the loop (VCtrl2). This second Mach-Zehnder is necessary to avoid the signal to circulate inside the loop indefinitely.

The third signal is the trigger signal and is used to select which lap is going to be visualized in the oscilloscope. In order to monitor the bit sequence in the desired lap, the trigger from the data generator is coupled with a bias-T to the trigger from the controller. As an example, figure 2 represents six laps inside the loop where the trigger is set to lap number three. With the controller device it’s possible to select the signals timings according to the delay in each lap and the number of laps.

The fiber used is 50 km long with an attenuation of 0.20 dB/km at 1550nm. The erbium fiber amplifier inside the loop is necessary to compensate all optical losses due to fiber attenuation, modulators, coupler and connectors in order to have unitary gain inside the loop.

C. Add-drop device

The optical add-drop devices are a key element in DWDM networks being used to remove and add selectively one or several optical signals from a DWDM system.

The add-drop architecture used in the test platform is based on an optical circulator, a fiber Bragg grating and an optical switch. When the WDM signal crosses the fiber Bragg grating, one of the channels is reflected back, passing through the circulator to the optical switch. The wavelength of the add-drop channel can be tuned by temperature control near 1550.8 nm. With the optical switch, it’s possible to choose whether to send back or to drop the channel and insert another one at the same wavelength, which is going to be coupled to the other channels by a 2X1 passive coupler.

C. Receiver

The receiver is composed by a PIN with a bandwidth of 18 Ghz with electrical amplification. Additional devices such as electrical filters and clock recovery units can also be used.

III. EXPERIMENTAL RESULTS

After the implementation of the proposed system described above, the experimental tests were made. Figure 3 is an image of the laboratory used to implement the setup.

Fig. 3 – Laboratory image

The system was tested with three optical channels at the wavelengths of 1549.2, 1549.9 and 1550.7 nm. The DWDM signal circulates inside the loop during 6 laps. Figure 4 shows the optical spectrum at the output of the emitter, after modulation.

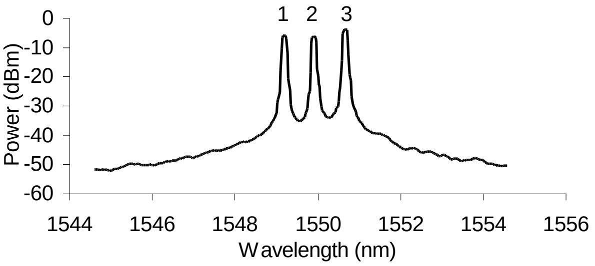

Fig. 4 - Optical spectrum after the emitter

Figure 5 represents the optical spectrum of the DWDM signal after circulating inside the loop and after the add-drop.

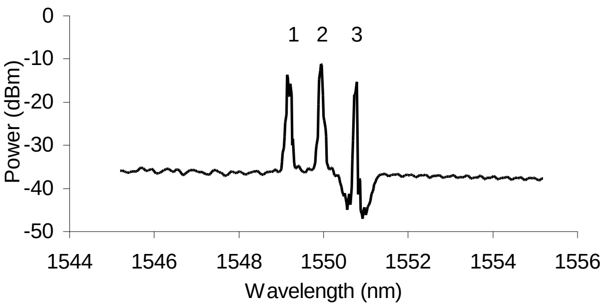

Fig. 5 – Optical spectrum after the add-drop.

The depression surrounding channel number three is a result of the process of removing and inserting the channel in the add-drop device.

If the channel number three is removed (figure 6), the optical spectrum of the channel will be as shown in figure 7.

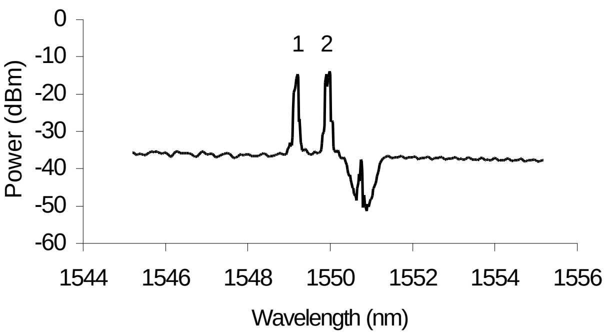

Fig. 6 – Optical spectrum after removing channel nº3.

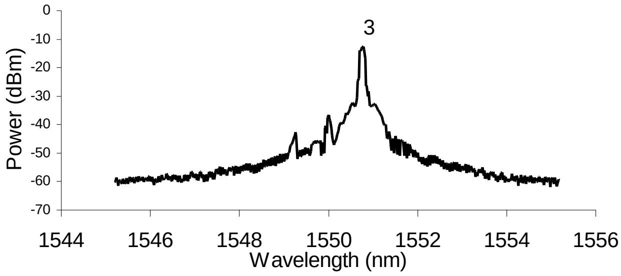

Fig. 7 – Optical channel of removed channel

Figures 8 and 9 illustrates the eye diagram for two distinct situations. The first one, in figure 8, is the eye diagram if the signal is received without any circulation inside the loop where figure 9 is the eye diagram after circulating during inside the loop six laps. This is possible to be done by selecting the appropriate number of laps in the loop controller.

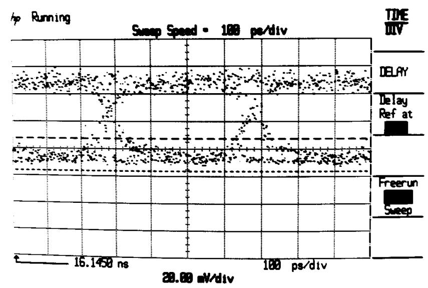

Fig. 8 – Eye diagram without circulation inside the loop

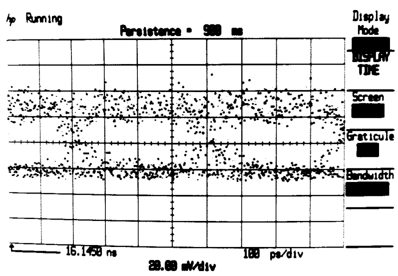

Fig. 9 – Eye diagram after six laps inside the loop

IV CONCLUSIONS

We have developed an optical test platform for laboratory experiments on high bit rates. In the system explained in this article, the platform works with three optical channels at 2.5 Gbit/s. With this system it’s possible to test add-drop functionality, propagation at long distances, enabling the study of the effects responsible for the performance degradation in optical networks such as homodyne crosstalk or the dispersion.

V FUTURE WORK

With this platform, more tests can be done, with more optical channels, larger distances of propagation and other devices, such as the optical cross connects, can be added to test other functionalities. A setup with cascaded optical add-drop multiplexers will be done in order to study the effects of homodyne crosstalk in bus and ring topologies [2].

VI REFERENCES

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