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Performance analysis of optical network based on optical add drop multiplexers with different MZI techniques

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ABSTRACT

This paper presents an investigation on the performance of an optical network in terms of crosstalk based on optical add drop multiplexers with Mach–Zehnder interferometer (MZI), MZI-semiconductor optical amplifier (SOA) and MZI-fiber Braggs gratings (FBG) techniques obtained at 8×10 Gbps with 0.1 nm channel spacing wavelength division multiplexing (WDM) transmission with optical add drop multiplexer (OADM) placed at the 20 km point of a 40 km link. It is found that the signal can be transmitted with least BER and better Q-factor with MZI-FBG based OADM and the worst case is found with the MZI-SOA based OADM.

1. Introduction

Wavelength division multiplexing (WDM) system is the state-of-the-art technology in optical communications. In a WDM optical network system, it is necessary to add or drop different wavelengths and optical add/drop multiplexer (OADM) is one of the key components to enable greater connectivity and flexibility of the network. Fibers grating based devices seem to be promising candidates for OADMs since they have the characteristics of small volume, inherently low loss, spectrally selective and easy to be coupled with optical fiber systems. An important technical issue for OADM design is the reduction of crosstalk, which can severely degrade system performance [1]. Crosstalk arises in OADMs through component imperfections and limits the performance of the system [2]. Optical crosstalk at the same wavelength as the information signal is generally referred to as homodyne crosstalk. It is particularly serious because it cannot be removed by filtering [3]. Optical add/drop multiplexer is an important network element. In the ring architecture, OADM can be introduced to make efficient use of network capacity, network protection, wavelength routing and many more good features [4]. An optical add/drop multiplexer is a device which is used in WDM system for multiplexing and routing different channels carrying wavelength of light from a single mode fiber (SMF). This is a type of optical device or node, which is generally, used for the construction of optical networks (high speeds) [5]. An OADM may be well thought out to be certain type of optical cross connects [6]. OADMs are elements that provide capability to add and drop traffic in the network (similar to SONET ADMs). They are located at sites supporting one or two (bi-directional) fiber pairs and enable a number of wavelength channels to be dropped and added reducing the number of unnecessary optoelectronic conversions, without affecting the traffic that is transmitted transparently through the node [7]. Many types of OADMs have been demonstrated based on different optical devices. These devices include Mach–Zehnder interferometers (MZIs) which is used to add and drop the channels as described in novel 2×2 multi wavelength optical cross connects based on OADM and optical switches [8]. Mach–Zehnder interferometers with fiber Bragg gratings (FBG) in which two FBGs are placed in the opposite arms of MZI [9] and MZI with semiconductor optical amplifiers (SOA) in which two SOAs are placed in arms of MZI as reported in [10]. Randhawa et al. [11] demonstrated the RingO (ring optical network) comprising of various nodes, and the signal is analyzed as it passes through each node in the network. It has been shown that there is no appreciable signal degradation in the ring network. It is seen that the signal keeps on improving as it passes through the successive nodes. Also when the whole ring structure is iterated with the help of spans, then improvement in the signal is observed. Singh and Kaler [12] described wavelength converter which plays an important role for increasing the capacity and flexibility of future broadcast network. The cross phase modulation based converter has high conversion efficiency at low input power. In order to improve the efficiency and wideband conversion range, the XPM is increasing by optimizing the semiconductor

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optical amplifiers–Mach–Zehnder interferometer (SOA–MZI) configuration. The XPM is improved by increasing the active region length and bias current of the SOA. Randhawa et al. [13] simulated, for the first time, wavelength converter for future broadcast networks at 40 Gb/s using low-cost semiconductor optical amplifiers. The performance analysis is carried out for an all-optical frequency converter based on cross-phase modulation in two semiconductor optical amplifiers arranged in a Mach–Zehnder interferometer configuration to evaluate the efficiency of conversion. Singh and Kaler [14,15] successfully simulated the 10×40 Gbit/s soliton RZ-DPSK WDM signals over 1050 km with spectral efficiency approaching 0.4 bit/s/Hz using semiconductor optical amplifiers as in-line amplifier. The cross-gain saturation of SOA can be minimized by settling crosstalk at a lower level by decreasing the differential gain and also investigated the impact of amplification factor, ASE noise power, crosstalk, quality factor and bit error rate for different differential gain. And also simulated 50 nm up and down wavelength conversion for a non-return to zero differential phase shift keying (NRZ-DPSK) signal using four-wave mixing in an optimized semiconductor optical amplifier at 10 Gb/s for the first time. At high-bit rate, the dispersion-induced broadening of short pulses propagating in the fiber causes crosstalk between the adjacent time slots, leading to errors when the communication distance increases beyond the dispersion length of the fiber [16]. Kaler et al. [17,18] investigated pre-, post- and symmetrical-dispersion compensation methods for 10 Gb/s non-return to zero (NRZ) links using standard and dispersion compensated fibers through computer simulations to optimize high data rate optical transmission. The influence of EDFA power and increase in length of each type of fiber has been studied to evaluate the performance of optical communication systems and also presented the power penalty analysis for approximate and realistic weight functions for combating the pulse broadening effects of group-velocity dispersion in a fiber-optic communication link using differential time delay method including higher-order dispersion terms. Riziotis and Zervas [19] studied the filtering performance of Bragg grating-based OADMs using theoretical system simulations. The implications of the non-optimum spectral characteristics of the coupler-based OADM are quantified and compared with other filter configurations. Jade and Wang [20] presented a novel characterization method for SOA–MZI switches which combines a pump-probe measurement with an interferometer bias scan. This enables optimal bias identification and better understanding of switching dynamics.

Till now, work is done on studying the feasibility of a WDM optical system based on an optical add/drop multiplexers, but very less work has been carried out to simulate the design of OADMs using different techniques, so that optimization can be done by avoiding the hardware costs involved. The effect of crosstalk on BER and Q-factor using these techniques has not been analyzed properly. All these measures have been taken in this paper, to have the assessment of signal evolution, as it passes through the 8×10 Gbps wavelength division multiplexing transmission (0.1 nm channel spacing) with OADMs placed at the 20 km point of a 40 km link.

The paper is organized into four sections. Section 1 presents the introduction. Section 2 presents the simulation set-up of the system and the description of its components. Section 3 includes the discussion of the results for the networks based on optical add/drop multiplexers with MZI, MZI–SOA and MZI–FBG. Section 4 presents the conclusion about the feasibility of the system.

2. Simulation set up

An optical transmission link consists of three stages i.e. transmitter, optical add drop multiplexer and receiver as shown in Fig. 1. As OADM has four ports namely input port, add port, drop port and output port. Eight channels (Tx) with different center frequencies i.e. 193.15 THz, 193.25 THz, 193.35 THz, 193.45 THz, 193.55 THz, 193.65 THz, 193.75 THz and 193.85 THz are fed to the input ports. A channel with frequency 193.15 THz is dropped to the drop port and the same frequency is added to the add port. Each transmitter is composed of data source, NRZ rectangular driver, laser source, optical amplitude modulator. Data source generates a binary sequence of data stream. Data source is customized by baud rate, sequence, logical. Laser block shows simplified continuous wave (CW) Lorentzian laser. The model has eight center emission frequencies, 1 mW CW power, ideal laser noise B.W., 10 FWHM line width and laser random phase. The output from the driver and laser source is passed to the optical amplitude modulator. Modulation driver here generates data format of the type NRZ rectangular with a signal dynamics i.e. low level −2.5 and high level +2.5. The pulses are then modulated using MZ modulator at 10 Gbps bit rate. The transmitters are followed by a fiber link of 20 km and an OADM in the circuit which has filter B.W. 40, insertion loss 3 dB, bandwidth reference 18 and add/drop frequency 193.15 THz. The OADM crosstalk is varied through parametric run from −90 dB to −10 dB. Further, it is followed by another fiber link of 20 km, splitter and receiver. In MZI based optical add/drop multiplexer, the optical signal pass through the different sections i.e. variable attenuator where 3 dB insertion loss is defined, and are fed to the splitter, ideal dual arm Mach–Zehnder interferometer which has B.W 40 GHz, delay (ps) 25 and tuning frequency/wavelength 193.5 THz/1549.31502842; 3 dB coupler and combiner. The channel which is to be selected from input port passes through splitter, band pass filter which has 15 number of stages, center frequency 193.15 THz, −3 dB two sided B.W. 40 GHz, splitter, combiner and finally the signal is dropped to the drop port of the OADM. To the add port, the signal passes through variable attenuator where 3 dB insertion loss is defined and are fed to the splitter, combiner, band pass filter and again combiner. Finally the output is taken from output port and crosstalk is defined between add and drop channels by making use of variable attenuator between the propagating signals as shown in Fig. 2. Similarly, in MZI–SOA based optical add/drop multiplexer, two similar SOAs are used in the opposite arms of MZI with 3 dB coupler as shown in Fig. 3.The parameters of SOA used in the simulation is as shown in Table 1. In MZI–FBG based optical cross connect, two similar ideal FBGs are used in opposite arms of MZI with 3 dB coupler as shown in Fig. 4.

Single receiver is composed of optical raised cosine filter, PIN photodiode and low-pass Bessel filter. Electrical scopes are used to observe change in performance.

Optical filter component implements a raised cosine transfer function filter having band pass filter synthesis, 1 as raised cosine exponent, 0.2 raised cosine roll off, 193.15 THz center frequency, 40 GHz B.W.

PIN photodiode is used to detect the optical signal, i.e. conversion into electrical signal. Its parameters are 193.0 THz/1553.32 nm

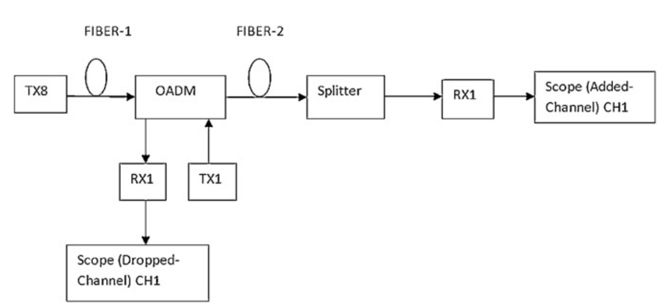

Fig. 1. System model.