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Investigation on interchannel crosstalk at ADM for an optical ring network

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Abstract

In this paper, we investigated the effect of interchannel crosstalk at ADM of a ring network at sweeping bandwidth of filters. Analysis has been done in a ring network [G.P. Agrawal, Fiber Optic Communication System, Wiley-interscience, New York, 1997; Tim Gyselings et al., Crosstalk analyses of multi-wavelength optical cross connects, J. Lightwave Technol. 17 (1999) 1273; R. Ramaswami, K.N. Sivarajan, Optical Networks: A Practical Perspective, Morgan Kaufmann, Los Altos, CA, 1998] that contains four nodes communication signal over two channels at 1552.2 nm. At the bit rate of 10 Gbps, ADMs at each node is modeled by using WDM add and WDM drop components. The distance between nodes is taken 12.5 and 25 km and an ideal amplifier is inserted just before one of the node to compensate for the total fiber loss in the ring. Dispersion and nonlinear effects of fibers are disabled to observe the crosstalk effect of ADM at sweeping bandwidth from 10 to 40 GHz of fourth-order Bessel filters.

1. Introduction

Optical networks are high-capacity telecommunication networks based on optical technologies and components, which provides routing, grooming and restoration at the wavelength level and wavelength-based services. Ring topology is preferred over mesh network because the number of links is reduced in ring topology. Ring networks provide standby links, share the load and have better resilience. In a ring network, interchannel crosstalk can arise from any of the sources like add–drop multiplexer (ADM), an optical switch, an amplifier, router and XPM. In such cases, a particular signal can accumulate crosstalk from different elements and channels. Some of the key components of optical ring networks are Erbium-doped fiber Amplifier (EDFA) and ADMs.

EDFA is a crucial element in optical networks and in an optical or IR repeater that amplifies a modulated beam directly, the need for optoelectronic and electro-optical conversion no longer exist. In a WDM system ADM is used to selectively add and drop any wavelength channel at intermediate node without affecting other channels transmitted simultaneously. ADM enhances networks flexibility and capacity as dropped wavelength can be reused [1–3].

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The ring networks, utilizing WDM transmission and wavelength routing, have been identified as an efficient means of implementing ultra capacity networks for interoffice application [4,5]. The recent deployment of high-capacity wavelength-division-multiplexed (WDM) transmission systems opens the way to a new network concept – namely the all optical network (AON). Taking advantage of WDM, AON should implement many network functions at the optical level [3]. In particular, optical add/drop multiplexers (OADMs) and optical cross connects (OXCs) would provide wavelength routing capabilities, so that each channel signal could be optically routed through the AON according to its own wavelength path. However, as reported in [6], one of the most serious limitations arises when considering the optical crosstalk. Node components could actually exhibit non-ideal features, resulting in small leakage of undesired channels: as an example, at the output of an OADM, the add channel may experience the detrimental effect of the residual drop signal.

The highest impairments arise from the beating between simultaneous "marks" in both the channel and crosstalk signals, provided that the resulting interferometric noise is not suppressed by the usual electrical filter at the receiver (in-band crosstalk) [7]. In this paper, we investigated the effect of interchannel crosstalk at ADM to a ring network at sweeping bandwidth of filters.

2. System description

This network contains four nodes that communicate over two channels at 193 and 193.1 THz, as shown in Fig. 1. *Four nodes* are all *transceivers* and they are interconnected with each other through *single mode fibers*. All the four Transceivers are modeled on *fourth-order Bessel filters* having 16 dBm sensitivity. Before Node 2 an optical amplifier (*EDFA*) with gain 10 dB and noise figure 4 dB has been included. In this network the bandwidth of three transceivers was kept fixed at 10 GHz and that of one (Node 2) was varied as iterations from 10 to 40 GHz

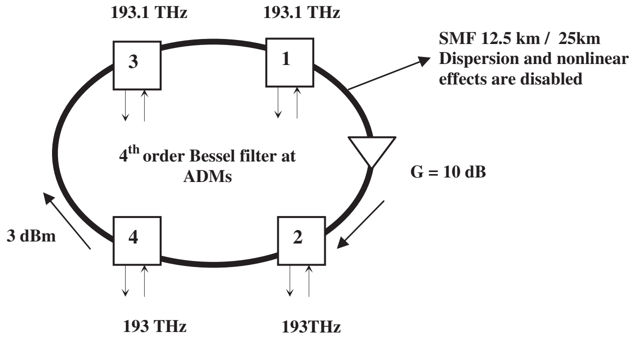


Fig. 1. A ring network with 4 nodes.

Table 1

Laser line width = 10 MHz
Laser noise threshold = −100 dB
Extinction ratio = 30 dB
Responsivity = 1 A/W
Dark current = 10 nA
DGD const. = 3 ps/km
Birefringence const. = $5\,\mathrm{m}^{-1}$
$Nz = 2.6 \times 10^{-20}\,\mathrm{m}^2/\mathrm{W}$
Peak Raman gain coeff. = 9.9×10^{-14} m/W
Pump λ of peak = 1000 nm
Raman self shift time = 5 P s

The ring shown in Fig. 1 is ended with a ring control component, which can circulate the signals around the ring for a given number of times. The distance between nodes is taken 12.5 and 25 km and we inserted an ideal amplifier just before node 2 to compensate for the total fiber loss in the ring. The simulation is done at 10, 20, and 40 Gbps at a wavelength of 1552.52 nm, power level 3 dbm. The other parameters are mentioned in Table 1 given below. Dispersion and nonlinear effects of fibers are disabled to observe the crosstalk effect of ADM.

WDM add and drop components are created by using fourth-order Bessel filters. The results for Q factor, eye closure and log of min BER have been reported for both the cases (12.5 and 25 km) by sweeping the bandwidth of filters of one node only from 10 to 40 GHz.

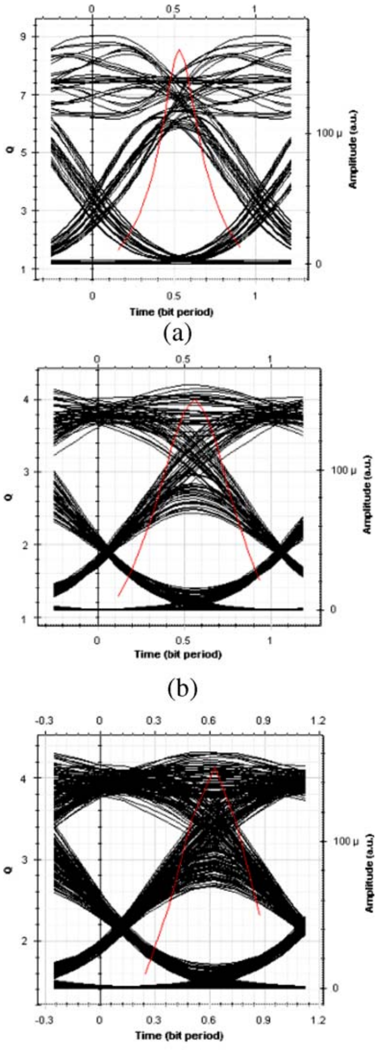
The Transceiver Subsystem comprised of a pseudo-random generator which generates bits at 10 Gbps, a CW laser as an optical source, a Mach-Zehnder Modulator, a WDM add and drop multiplexer, an attenuator, a PIN diode detector and a fourth-order Bessel low pass filter whose cutoff frequency is 0.75 bit rate.

3. Analysis

In order to simulate the network the bandwidth of Nodes 1, 3, 4 was fixed at 10 GHz and for Node 2 it was varied as iterations from 10 to 40 GHz:

Sweep iteration no.	Bandwidth (GHz)
1	10.0
2	17.5
3	25.0
4	32.5
5	40.0

In order to see the performance of the network we plotted the "*Eye-Diagrams*" using the BER Analyzer.



(a)

(b)

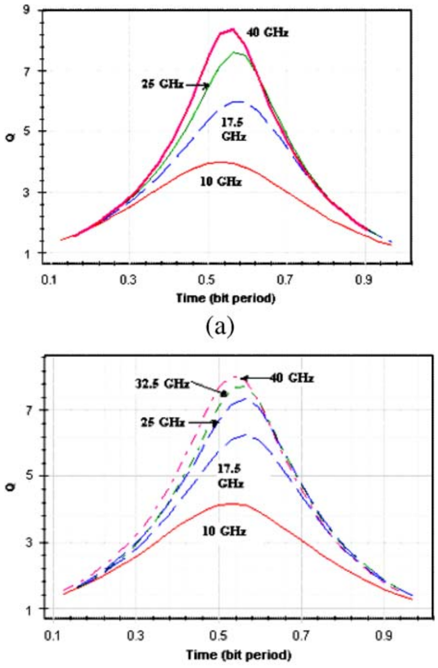
(c)

Fig. 2. Eye diagram at filter bandwidth of 40 GHz, fiber length of 12.5 km between each node and different bit rate (a) 10 Gbps, (b) 20 Gbps, and (c) 40 Gbps.

Fig. 2 shows that Q factor reduces from around 8 at 10 Gbps to around 4 at Gbps 20 and is about 4 at 40 Gbps. Also, eye opening is much wider at 10 Gbps and reduces as bit rate increases. At 40 Gbps, lot of crosstalk has been introduced due to increased dispersion.

Fig. 3 shows that with the increase in iteration, i.e. with the increase in bandwidth of the filter, Q factor is enhanced. Also as the length of fiber increases from 12.5 to 25 km, value of Q factor is reduced slightly.

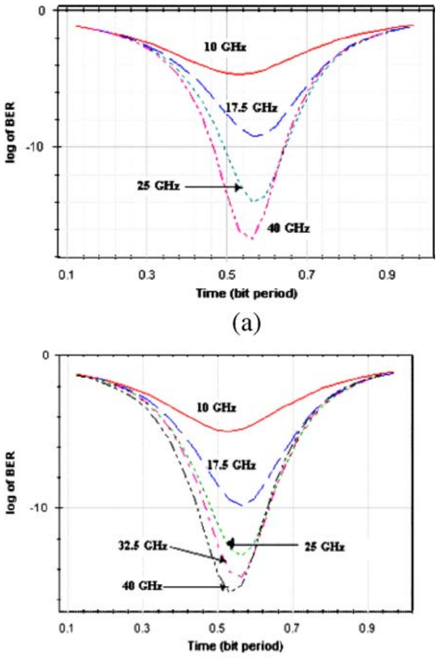
Fig. 4 shows that minimum BER is reduced slightly for filter bandwidth of 10, 17.5, 25, and 40 GHz as distance between two nodes increases from 12.5 to 25 km.



(a)

(b)

Fig. 3. Q factor curves at different filter bandwidth, fiber length of (a) 12.5 km and (b) 25 km between each node and bit rate of 10 Gbps.

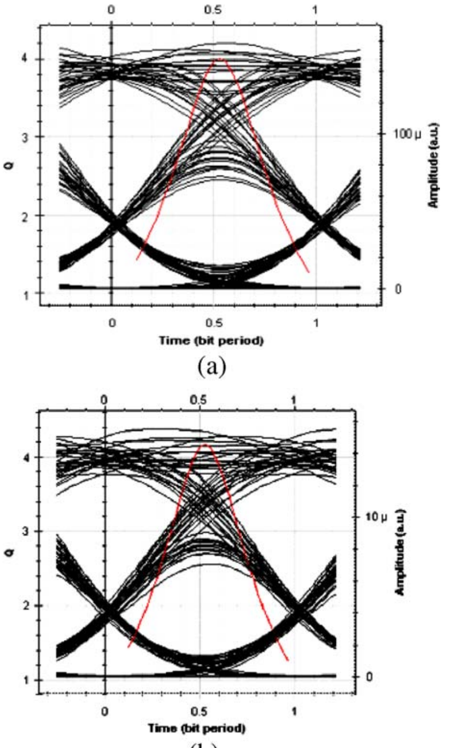


(a)

(b)

Fig. 4. Minimum BER curves at different filter bandwidth, fiber length of (a) 12.5 km and (b) 25 km between each node and bit rate of 10 Gbps.

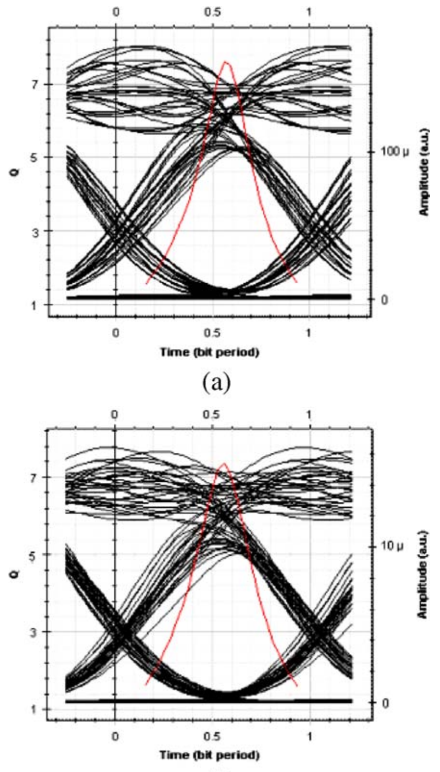
From Figs. 5 to 8 it is observed that with the increase in fiber length from 12.5 to 25 km, performance of the system slightly deteriorates and crosstalk increases.



(a)

(b)

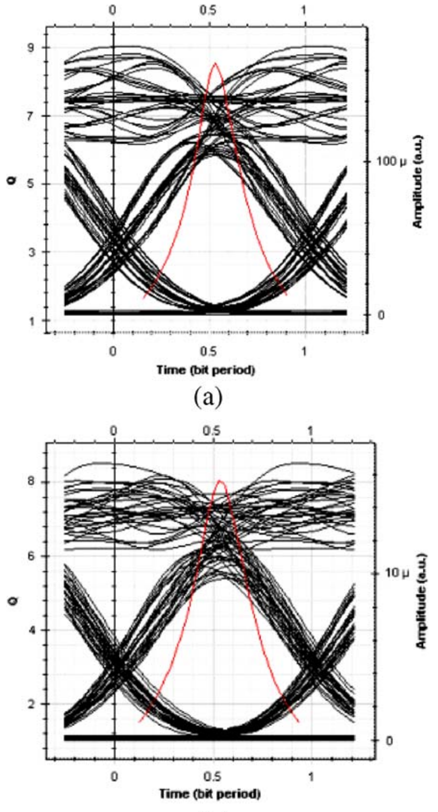
Fig. 5. Eye diagram at filter bandwidth 10 GHz, bit rate of 10 Gbps and fiber length of (a) 12.5 km and (b) 25 km between each node.



(a)

(b)

Fig. 6. Eye diagram at filter bandwidth 25 GHz, bit rate of 10 Gbps and fiber length of (a) 12.5 km and (b) 25 km between each node.



(a)

(b)

Fig. 7. Eye diagram at filter bandwidth 40 GHz, bit rate of 10 Gbps and fiber length of (a) 12.5 km and (b) 25 km between each node.

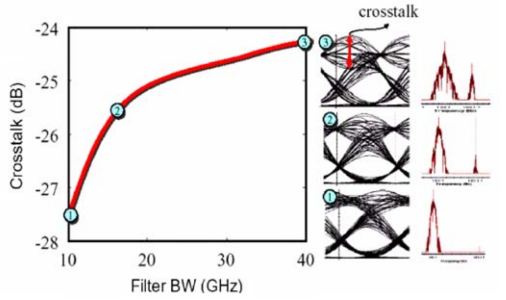


Fig. 8. Crosstalk variation with change in filter bandwidth.

4. Conclusions

The performance of the ring network varied with each sweep iteration, i.e. as the bandwidth of the WDM add and drop multiplexer was increased from 10 to 40 GHz in steps, the *Q* factor of the system, the eye opening increased while the minimum BER was further reduced. The crosstalk on the other hand increased. With increase in bit rate (speed), the performance of the ring optical network deteriorated. With 10 Gbps the network was more immune to crosstalk than 20 or 40 Gbps. Also with increase in length of the optical fiber connected between the nodes, crosstalk and the dispersion effects became more prominent. For a 12.5 km fiber length system the eye opening was much wider as compared to that in the 25 km fiber length network.

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