Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN:1673-064X
E-Publication:Online Open Access
Vol: 65 Issue 03 | 2022
DOI 10.17605/OSF.IO/TAS7W

COMPUTATIONAL BIT ERROR RATE ANALYSIS OF AN ALL-OPTICAL PACKET SWITCH EMPLOYED ON RECIRCULATION FIBER LOOP BUFFER

VIVEKANAND M[1], DEMISSIE J[2], BALACHANDRAN R[2] and VIPIN P[1]

[1]Department of Physics, Alliance University, Bangalore - 560076, India
[2]Department of ECE, School of Electrical Engineering and Computing, Adama Science and Technology University, P.O. Box No. 1888, Adama, Ethiopia.

ABSTRACT:
Optical data storage with fiber loop and ultra-fast optical switching with nonlinear optical loop mirror (NOLM) have been regarded as an ideal all-optical processing device respectively. In this paper, optical loop buffer combined (OLB) with the NOLM switch devices have been integrated to provide an efficient buffering-switching device to curb the signal contention. Various limitations using the proposed device have been analyzed in order to obtain an error-free process for the maximum rounds of buffering circulations.

1. Introduction*:* In the optical switches buffering can be easily execute using fiber delay lines. Many delay line buffers are possible. Escalating transmission rates in telecommunication networks have prompted extensive interests in the optical communication research. Optical signals transmitted directly in the optical layer without resorting to OEO conversion, has emerged as a promising technology for the long-term evolution of optical networks. Several techniques using fiber delay line (FDL) as storage have been proposed. However, a longer FDL is required for a significant buffering time. Thus, this has prompted the invention of several techniques based on fiber loop recirculation [1], meant for optical buffering purposes. Size of the buffer loop is fix without depending on the length of buffering time required, and is much compact in size as compared to FDL. NOLM has been proven as an efficient optical demultiplexer that provides high speed switching [2]. In this paper, the proposed combination of optical loop buffer (OLB) with NOLM is utilized to provide an efficient matching of optical buffering-switching device for curbing the signal contention.

2. System model

The idea of NOLM demultiplexer has been evolved from the Sagnac interferometer. NOLM is preferred due to its higher switching speed, but lower operating power and simpler setup. In a NOLM demultiplexer, the high intensity control signal from the WDM coupler will induce XPM effect on the clockwise input signal. Thus, it will cause the input signals to experience a refractive index variation due to Kerr effect. In the optical communication, all-optical buffer device is unavailable. Furthermore, the FDL is impractical to be implemented for higher buffering period. Hence, the optical loop buffer that has nearly identical architecture to the NOLM switch suites ideally for the optical buffering services. It is important to observe that signal entering the NOLM switch will be split and co-propagate bi-directionally, while it is not the case for OLB. This is because NOLM switch requires the nonlinear effects, such as XPM, for its

Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN:1673-064X
E-Publication:Online Open Access
Vol: 65 Issue 03 | 2022
DOI 10.17605/OSF.IO/TAS7W

switching functions. In view of their respective advantages, the combination of NOLM demultiplexer and OLB will provide an outstanding optical buffering-switching service for the optical networks. The OLB is located before the NOLM switch in order to reduce contention as well as the amount of reflected signals by the switch. When the input signal arrives at the switch (as shown in Fig. 1), two routes are available for chosen. Input signal that does not require buffering will be switch to the NOLM, without entering the OLB.

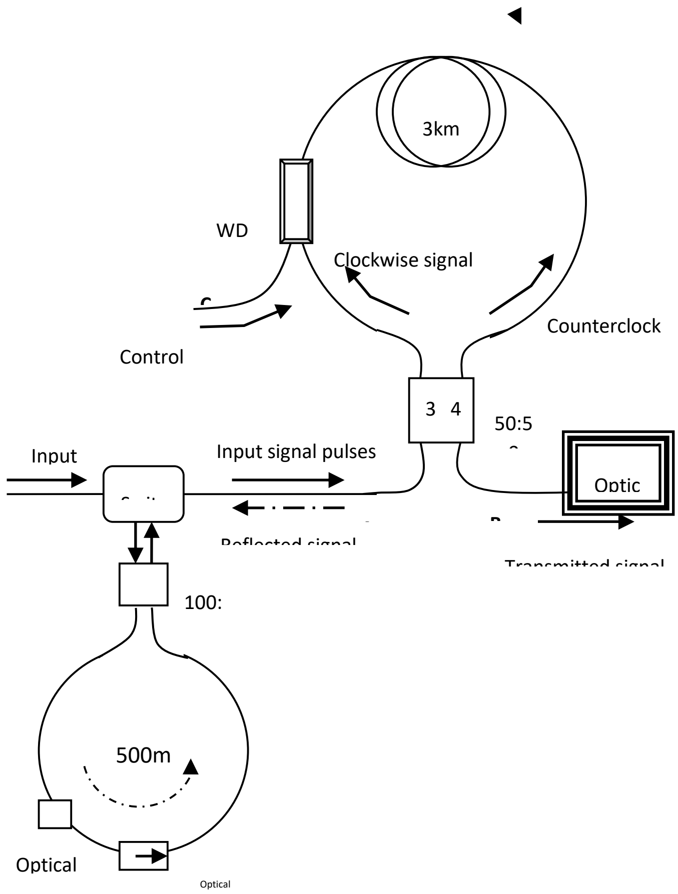

Fig.1 ***Schematic diagram of an OLB combined with the NOLM switch (2)***

3. Theoretical analysis

Though the proposed optical buffering and switching device tends to improve the signal throughput of the optical networks, the demultiplexed signal is un-avoided from degradation caused by various noise sources. The noises involved are identified as thermal noise, shot noise and several types of beat noise that related to the spontaneous emission. The OLB allows the signal to recirculate within the fiber loop for a certain numbers of rounds. As a result, noises are accumulated for every circulation. The reduced received power at the receiver after the recirculation, P_S is given by:

$$P_s = P_N 10^{-z/10} \qquad (1)$$

ISSN:1673-064X
E-Publication:Online Open Access
Vol: 65 Issue 03 | 2022
DOI 10.17605/OSF.IO/TAS7W

where P_N and z signify the output power after N loops of circulations and the amount of data signal attenuation in decibel (*dB*), respectively. P_s will be the input signal power of the buffered signal that enters the NOLM switch. The nonlinear Schrodinger (NLS) equation is utilized when a long length fiber is employed, as the dispersive and nonlinear effects are significant in a long fiber. Thus, the signal that propagates in the clockwise, counterclockwise direction and control pulse that satisfies the NLS equation can be written as:

$$\frac{\partial A_3}{\partial z}+\frac{i\beta_{2s}}{2}\frac{\partial^2 A_3}{\partial T^2}=i\gamma_s\left(\left|A_3\right|^2+2\left|A_c\right|^2\right)A_3 \quad (2)$$

$$\frac{\partial A_c}{\partial z}+\beta_1\frac{\partial A_c}{\partial T}+\frac{i\beta_{2c}}{2}\frac{\partial^2 A_c}{\partial T^2}=i\gamma_c\left(\left|A_c\right|^2+2\left|A_3\right|^2\right)A_c \quad (3)$$

$$\frac{\partial A_4}{\partial z}+\frac{i\beta_{2s}}{2}\frac{\partial^2 A_4}{\partial T^2}=i\gamma_s\left|A_4\right|^2 A_4 \quad (4)$$

where z is the distance from port 3 along clockwise direction, β_{2S} and β_{2C} are the GVD parameters for signal and control pulse respectively, T is the time variable in retarded frame, γ_S and γ_C are the nonlinear coefficient parameter of signal pulse and control pulse respectively.

Besides, the signal pulse in the clockwise direction (A_3), counterclockwise direction (A_4) and the control pulse (A_C) are listed as follows:

$$A_3=\left(1-K\right)^{1/2}\left(P_1\right)^{1/2}\left(P_0\right)^{1/2}e^{-t^2/2\left(T_{O1}\right)^4} \quad (5)$$

$$A_4=j\left(K\right)^{1/2}\left(P_1\right)^{1/2}\left(P_0\right)^{1/2}e^{-t^2/2\left(T_{O1}\right)^4} \quad (6)$$

$$A_C=\left(P_2\right)^{1/2}\left(P_0\right)^{1/2}e^{-t^2/2\left(T_{O2}\right)^4} \quad (7)$$

where K represents the coupling ratio, P_1 and P_2 are the peak power for the signal pulse and control pulse respectively, P_0 is the input power, t is the time variable, T_{01} corresponds to the full width at half maximum (FWHM) for the signal pulse.

The control pulse from WDM coupler will couple and co-propagate with the desire section of clockwise propagating signal that required for transmission. The signal pulse that is transmitted out of the fiber loop is written as:

$$\text{signal out}=(1-K)^{1/2}E_4+j\left(K\right)^{1/2}E_1 \quad (8)$$

where E_1 and E_4 represent the clockwise and counterclockwise propagating signals respectively. The values of E_1 and E_4 are calculated numerically by using the split-step Fourier method (SSFM).

To evaluate signals undergone the optical buffering and switching devices, the BER used will be given as:

Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN:1673-064X
E-Publication:Online Open Access
Vol: 65 Issue 03 | 2022
DOI 10.17605/OSF.IO/TAS7W

$$BER = \frac{1}{2} erfc\left[\frac{I_1}{\sqrt{2}\left(\sigma_1 + \sigma_0\right)}\right] \qquad (9)$$

where $I_1 = RP_{1a}$ and P_{1a} represents the output power from the switch.

Result and discussion: Numerical analysis is performed to achieve an error-free optical buffering-switching service with the system model as illustrated in Fig. 1.The primary objective of the results depicted below are to obtain the maximum rounds of recirculation for the data packets with 512 bits per packet. Fig. 2 demonstrated the BER analysis of the buffered signal after various loop recirculations within the OLB.

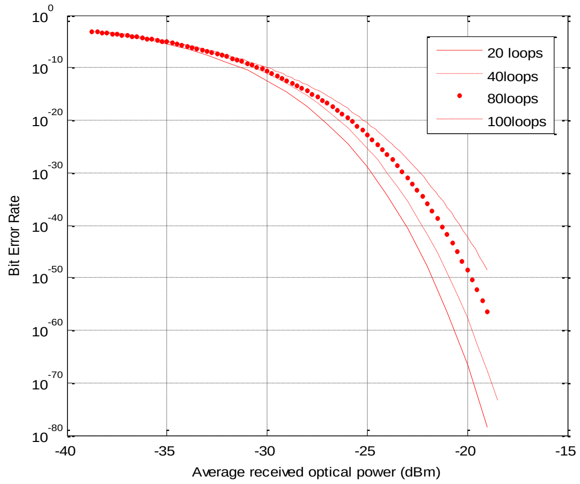

Fig.2 ***BER vs. received optical power with various loop recirculation for the buffering device.***

In Fig.2, input signal that experienced 20 circulation buffer outperformed the other experiments with higher loop circulations. The higher the number of circulations, the BER will deteriorate further. This phenomenon mainly attributes to the intensity fluctuation of the signal caused by various sources of noise as discussed above.

Conclusions

A new optical buffering-switching device has been proposed in this paper. The device is designed using the optical fiber loop architecture to provide a compact but efficient optical buffer and an ultra-fast optical switching service. The simulated results have revealed that signal propagating through fiber loops suffered intensity fluctuations due to various sources of noise.

References

1. K. L. Hall and K. A. Rauschenbach, “All-Optical Buffering of 40-Gb/s Data Packets,'' *IEEE Photonics Technology Letters*, 1998,vol. 10, pp. 442-444 , doi: : 10.1109/68.661437
2. M. F. Tang, F. M. Abbou, A. Abid, V. N. Mishra, and H. T. Chuah, “Packet loss rate of an optical burst switch with nonlinear optical loop mirrors,” *IEICE Electronics Express*, 2006, vol.3,

no.11, pp.243-248, doi: 10.1587/elex.3.243

3. G. P. Agrawal, Fiber-Optic Communication Systems, *Wiley-Interscience Publication , N.Y.*, 1997.
4. K. Uchiyama, H. Takara, T. Morioka, S. Kawanishi, M.Saruwatari, “Effects of control-signal pulse walk-off on BER performance of nonlinear optical loop mirror demultiplexer,” *Electron. Lett.*, 1993, Vol. 29, pp. 1313-1314.