Investigations on 10 Gbps Electro Absorption Modulator Based Wavelength Converter

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***Abstract* - Wavelength conversion using Electro Absorption Modulator (EAM) is an effective way that performs signal conversion in high traffic networks. It allows better utilization of available network bandwidth. In this work, EAM with Radio Frequency (RF) generator has been investigated for cost effective solution to eliminate the requirement of additional pumps. Performance analysis of EAM as wavelength converter using NRZ line coding has been explored for varied input power: -3 to 10 dB and data rates: 1, 3 and 10 Gbps. It has been observed that with the increase of input power; Q-factor and efficiency of the conversion increases due to Cross Absorption Modulation (XAM). System investigation further analyzed for modulation index of EAM varied from 0.6 to 0.9 and linewidth varied from 0 to 500 MHz. Better performance of system reported at higher modulation index value i.e 0.9 and lower value of linewidth i.e. 10 KHz . The results demonstrate the capability of EAM at 10 Gbps.**

***Index Terms*- EAM, XAM, Wavelength conversion, BER, MZM**

I. INTRODUCTION

Wavelength conversion plays a key role in future flexible networks using Wavelength Division Multiplexing for high speed digital optical systems. In recent years, a number of optical network functions have been demonstrated using an electroabsorption modulator (EAM) based on the cross-absorption modulation (XAM) [1] namely; demultiplexing [2, 3], trans-multiplexing from wavelength division multiplexing (WDM) to optical time division multiplexing (OTDM) [4], optical label encoding /recognition [5], an all-optical limiter [6], short pulse generation [7], wavelength conversion [8] and all-optical regeneration [9]. Use of electro absorption modulator (EAM) to replace the complicated system of assembling discrete devices is recommended. It can reduced package cost, power consumption and system size [10]. Many techniques have been proposed to realize wavelength conversion using Cross Gain Modulation (XGM) effects in semiconductor optical amplifier (SOA's) [11]. Usually, Machzender interferometer wavelength converter based on SOA's (MZI – SOA)[12] is preferred having small size as well as the possibility of integration with other device. Such SOA's has limited frequency response. Recently, Highly non linear fiber (HNLF) has attracted much attention for optical signal processing [13] because of high nonlinearities but requires additional pump source to generate FWM. However, it increases overall system cost [14]. EAM has several advantages such as (1) Small Size (2) High Modulation Efficiency (3) high power operation (4) Elimination of External pumps [15]. The underlying principle XAM has advantage over FWM, by eliminating the requirement of external pumps in the wavelength conversion. Another convenient feature is that an EAM can be integrated with distributed feedback laser diode on a single chip to form a data transmitter in the form of a photonic integrated circuit. On comparison with direct modulation of the laser diode, here a higher bandwidth and reduced chirp can be obtained. An EAM possesses faster absorption recovery time (i.e., less than 10 ps) and also experiences reduced chirp on the output signal (ideally zero or negative) as compared to other optical devices (e.g., semiconductor optical amplifiers). Furthermore, it has been suggested that an EAM is (theoretically) capable of handling tera-hertz modulation rates. These capabilities make EAMs a better choice for such high-speed operations in comparison with semiconductor optical amplifier based subsystems.

In this paper, the wavelength conversion efficiency of EAM (Electro Absorption Modulator) wavelength converter at different bit rates and power has been investigated. The work found the wavelength conversion efficiency of EAM using single laser source at varied input power and data rates such as 1, 3 and 10 Gbps. Effects of laser linewidth and modulation index on XAM have also been studied in terms of received power and BER.

II. MODEL DESCRIPTION

Fig 1(a) schematically shows the simulation model of the wavelength conversion. Data source at 10 Gbps, CW laser at 1549 nm center emission wavelength with variable power source signal is fed as a reference signal. A MZM modulator is employed to convert electrical signal into optical driven by NRZ line coding. PS (Power splitter) splits up signal into two equal power branches. EAM is brought into play as a medium to broaden the frequency spectra over different range of frequencies. A sinusoidal signal at 300 GHz frequency has been generated and fed to EAM (Electro Absorption Modulator) modulator. Due to non linear effect, EAM (Electro Absorption Modulator) modulator generates non linearities. A Bessel optical filter tuned at a particular frequency is used so as to detect the signal at that particular frequency. The EAM (Electro Absorption Modulator) is a commercial device. It is a polarisation independent, tensile strained InGaAsP multiple quantum well modulator optimized for external modulation in the C-band up to 40 GHz bandwidth. The eye diagram of converted ouput signals is observed.

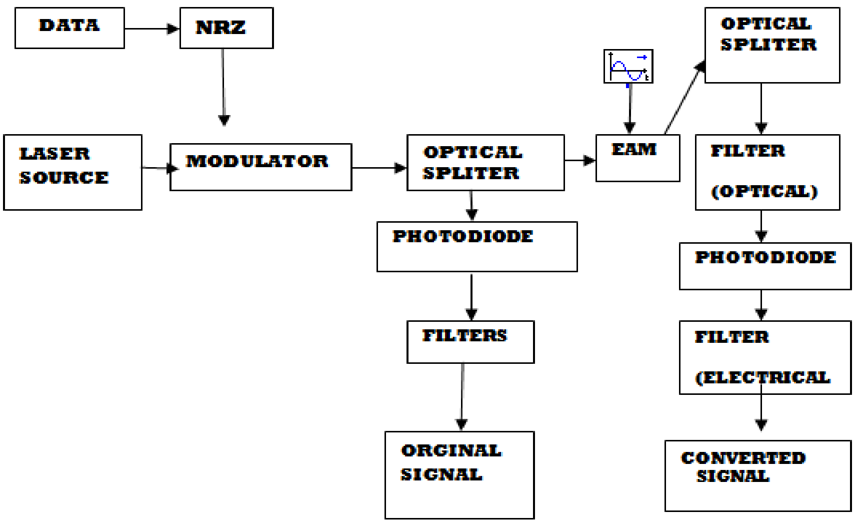


Fig 1. (a): Schematic Block diagram to investigate the performance of EAM as wavelength converter

III. Mathematical Representation Of EAM Based Wavelength Converter

The performance of optical subsystems (i.e., for wavelength conversion) utilizing an EAM is dependent on various factors such as the modulator chirp, the average optical power transmitted, and the extinction ratio of the device [16]. Assuming that the optical input signal is E_{in}, the following equation describes the mathematical behavior

$$Eout(t) = Ein(t)|T(t)|\; ej\varphi(t)$$

where *Ein(t)* is the input signal, the term *φ(t)* defines the phase variations and | *T(t)*| stands for the absolute value of transmission function. The phase variations result from the refractive index variations that lead to chirp on the output signal. Also this can be written as

$$Eout(t) = Ein(t).\sqrt{Mod(t)}.\exp\left(\frac{j\alpha}{2}, In\left(Mod(t)\right)\right)$$

where $E_{out}(t)$ is the output optical signal, α is the chirp factor, and Mod(t) is defined as

$$M\,od(t) = (1 - MI) + MI.modulation(t)$$

where MI is the modulation index and modulation(t) is the electrical input signal. The electrical input signal is normalized between 0 and 1.

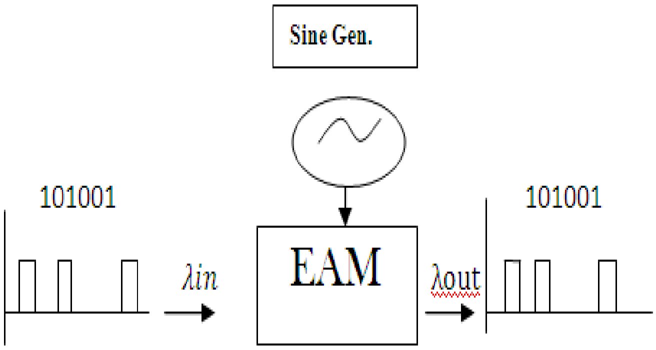


Fig.1(b) Basic principle of EAM as wavelength converter.

Fundamentally, EAM works on modulation of a percentage of photons absorbed in a optical waveguide by varying the strength of electic field applied across the wave guide.This situation is illustrated in Fig. 1(b) where the basic principle of operation for an EAM as an optical wavelength converter is shown. The wavelength conversion in an EAM can be achieved through the cross-absorption of the signal using input signal cw laser and radio signal from sine generator.

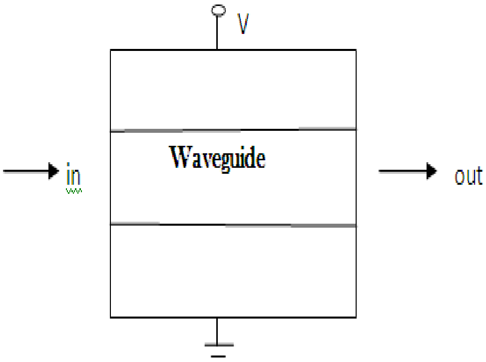
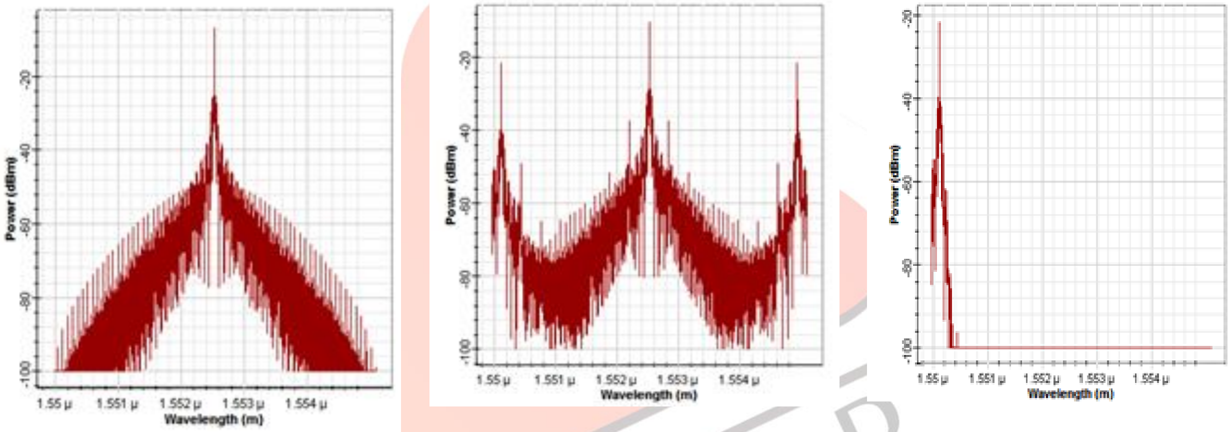


Fig.1(c) EA modulator

Table 1. Parameters used in simulation.

Description	Values
Wavelength, λ	1549 nm
MZM , ER	30 dB
EAM's modulation Index	0.60-0.90
Receiver's Responsivity	1 A/W

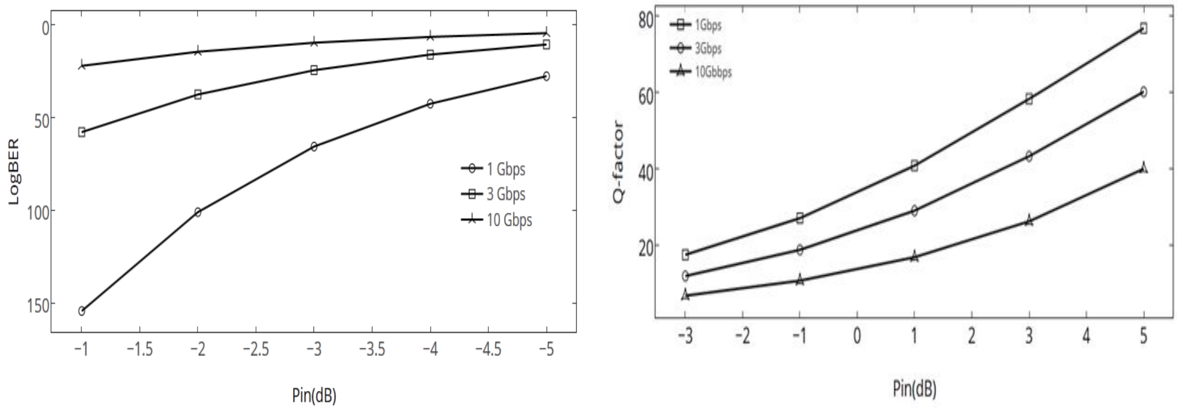
IV. RESULTS AND DISCUSSION



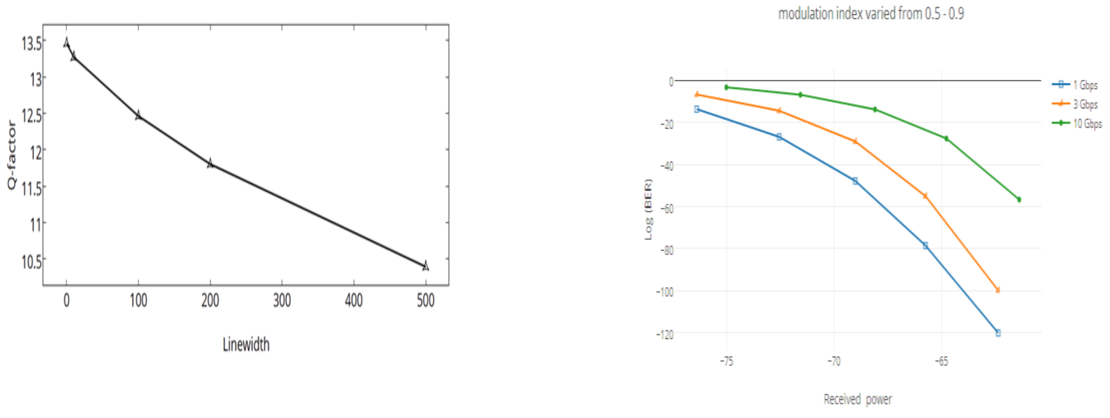
(a) (b) (c)

Fig 2: Spectrum of signal after (a) MZM (b) EAM (c) Bessel Filter

Fig. 2(a) represent the spectrum of orginal signal after passing through Mach-zehnder Inferometer with centre wavelength at 1552 nm. Fig. 2(b) portrays the spectrum of signal after passing through EAM with positive and negative deviation around the centre wavelength. Positive and negative deviations occur due to non linear effect of EAM. Figure. 2(c) shows the sliced spectrum of filtered wavelength at 1550 nm after EAM using a Bessel optical filter with bandwidth 20 GHz in case of 10 Gbps system. However, results are obtained at lower data rates such as 1 Gbps and 3 Gbps with filter Bandwidth 2 GHz and 6 GHz respectively.



(a) (b)



(c) (d)

Fig 3.Graphical Representation of System for various parameters (a) Log BER Vs Pin (b) Quality factor of converted signal Vs Pin (c) Linewidth Vs Q-factor at 10 Gbps (d) Log [BER] vs Received power

The main elements forming the structure of Simulation model as shown in Fig.1(a). The output of simulation model determines the behaviour for an EAM with the variations of input power, modulation index, linewidth, Q-Factor caused by change in absorption characteristics. Typical values of parameter used in simulation are provided in Table 1. Figure. 3(a) shows the variation of Log(BER) with input power. The Y-axis represent Log (BER) corresponding to the input signal power shown in dB on the X-axis. A variation in input power was applied using a sweep generator. At the lower values of power, BER is observed more than at higher powers. There is enhancement in Q-factor and system performance with the increase in the input power. At higher powers non-linear impairments increases and thus the efficiency of conversion as shown in Fig. 3(b).

Fig 3(c) demonstrates the effect of linewidth variation on Q-factor for the values of receiver's responsivity for wavelength as given in Table 1. A range of linewidth from 0 - 500 have been used to observe the effect on Q-factor for the bit rate of 10 Gbps. More spectrum broadening has been observed at higher value of linewidth. However in proposed system effect of linewidth can be seen from Fig.3(c). More Spectrum broadening has been observed at lower values of linewidth with high rate of wavelength conversion due to XAM. The modulation index (or modulation depth) of a modulation scheme describes by how much the modulated variable of the carrier signal varies around its unmodulated level. Fig 3(d) shows the effect of variation in modulation index from 0.6 –to 0.9 on the Log[BER] and Received power of converted signal and it is analyzed that more value of modulation index cause more light linked to ouput , as a result of which there is an improvement in Q-factor. Value of output power directly depends upon modulation index and varied linearly with the modulation index.

V. CONCLUSION

The demonstrated simulation of an EAM is suitable for the purpose of wavelength conversion. This model uses a sine generator and laser signal as an input by eliminating the requirement of extra pump sources. In order to facilitate the wavelength conversion, it is important to select the high modulation index value to get high performance of wavelength conversion. The wavelength conversion model has been used to determine the values for the input power with respect to the non linear coefficient (i.e. modulation index, linewidth) which are responsible for wavelength conversion of the output signal. Quality factor of 13.5 has been reported at 10 KHz linewidth for 10 Gbps data rate. Values of Q-factor 80, 60, and 40 has been observed at input power of 5 dB for 1, 3 and 10 Gbps respectively. At modulation index of 0.9, values of received power and BER are -62.35dB, 1.2×10^{-121} for 1 Gbps and -61.37 dB, 3.2×10^{-57} for 10 Gbps . The proposed work realizes the wavelength conversion by utilizing and incorporating EAM (Electro Absorption Modulator) as a medium for cross absorption modulation (XAM). In addition it was shown that at high powers (5-10 dB) and low values of linewidth such as 0 -10 MHz , enhanced overall performance of the Wavelength Converter.

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