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Performance Evaluation of RZ Format Wavelength Converter using Electro Absorption Modulator at Different Bit Rate

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Abstract

We have investigated electro absorption modulator (EAM) based wavelength conversion with radio frequency generator to eliminate the constraint of additional pump signal. This is the one of cost effective solution to design the wavelength converter. In this work the performance analysis of EAM based wavelength converter using RZ line coding has been investigated at different input power (-3dB to 10 dB) and at different data rate (1Gbps, 5Gbps and 10Gbps). It has been observed that due to Cross Absorption modulation (XAM) the quality factor and efficiency of converted signal increases as we increase the input signal power. System investigation further analyzed for modulation index of EAM varies from 0.6 to 0.95 and line width of laser source is varied from 0 to 500 MHz and observed the better performance of system reported at high modulation index value i.e. 0.95 and lower value of line width i.e. 10 KHz.

Keywords – EAM, XAM, Wavelength conversion, RZ format

Introduction

All-optical wavelength conversion can solve the problem like wavelength channel contention, and hence it is one of the key technologies to improve scalability of future all-photonic network. Variety of all-optical wavelength converters have been proposed and investigated so far. Various kinds of optical nonlinearity are possible to be utilized for all-optical wavelength conversion, although there is a significant problem of tradeoff between required optical power and response speed. For example, Kerr effect induced in silica fiber has subpicosecond response, but its efficiency is quite low and it requires several hundred milliwatt optical pump power to induce phase shift large enough to be utilized for wavelength conversion [1]–[5]. On the other hand, a semiconductor optical amplifier (SOA) is superior in efficiency due to its gain, and wavelength conversion with a few or submilliwatt pump power is possible [6]–[11]. However, its response time is in the order of a few tens of picoseconds. The optical nonlinearities induced in an electro absorption modulator (EAM) have a faster response than those induced in an SOA and a higher efficiency than those in silica fiber. Under typical conditions, the absorption recovery time is less than 10 ps and the required pulse power is less than one hundred milliwatts. For wavelength conversion of randomly coded signal, recovery time is required to be less than the bit-period to reduce patterning effect, which is the fluctuation of output power depending on the logical pattern of the input signal. Recently, highly non linear fiber (HNLF) has attracted much attention for optical signal processing [12] because of high nonlinearities but requires additional pump source to generate FWM. However it increases overall system cost [13]. EAM has several advantages such as small size, high modulation efficiency, high power operation and elimination of external pump [14]. The underlying principle XAM has advantage over FWM, by eliminating the requirement of external pumps in the wavelength conversion. Furthermore it has been suggested that EAM is (theoretical) capable of handling tera-hertz modulation rates and these capabilities makes EAM as better choice for high speed operations in comparison with semiconductor optical amplifier based subsystems.

Here in this paper RZ format EAM based wavelength converter at different bit rates and power has been investigated in detail. The input signal power and different data rates are two decisive operating parameters in wavelength conversion, so input signal power dependence and data rate dependence of wavelength conversion performance are studied in detail by monitoring eye diagrams of the converted signal and measuring the Q factor and of wavelength conversion. Effect of laser line width and modulation index on XAM have also been studied.

1. Model Description

Fig. 1 schematically shows the simulation model of wavelength conversion; the transmitter section consists of electrical driver, data source, laser and mach-zehnder modulator. The function of data source is to generate signal of 10 Gbit/s with RZ format. The electrical driver converts logical input signal in to electrical signal. The continuous wave (CW) laser sources generate laser beams at 1550 nm. The signals from laser source and data source are fed to mach-zehnder modulator, where information signal is modulated by laser source. The modulated signal is given to an optical splitter which splits up signal into two equal powers which can be seen by using optical spectrum analyzer. The output of splitter is applied to an EAM modulator which is medium to broaden the frequency spectra over different ranges of frequencies. A sinusoidal signal at 500 GHZ frequency has been generated and applied to EAM modulator. Due to non-linear effects of EAM multiple signals are produced at different wavelengths which are seen at the output of splitter by using optical spectrum analyzer. The receiver section consists of a Bessel optical filter, PIN photo detector, electrical filter, power meter, BER analyzer. The function of a Bessel optical filter is to select the desired band of signals and reject remaining signals. The photo-detector is used to convert an optical signal into electrical signal. Electrical filter is used to pass desired electrical signals and reject unwanted frequency signals. The BER analyzer is used to display quality factor and bit error rate of signal. Power meter is used to display the received power. EAM is a commercial device and is polarization independent, tensile strained InGaAsP multiple quantum well modulator optimized for external modulation in the C- band upto 40 GHZ bandwidth.

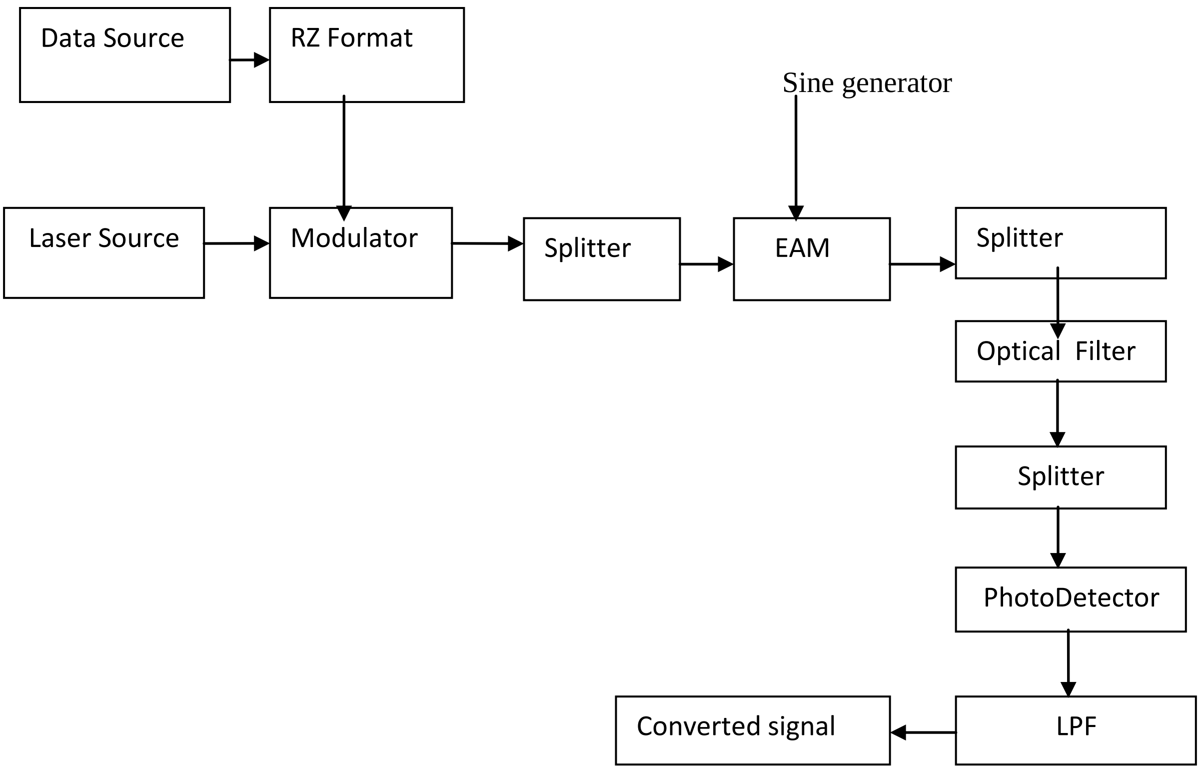

Fig. 1 Schematic Block diagram of RZ format wavelength converter

2. Physical Mechanism of EAM

Electro-absorption modulator (EAM) is a semiconductor device which can be used for modulating the intensity of a laser beam via an electric voltage. Fig. 2 shows the schematic of the Cross absorption saturation effect of an Electro-absorption modulator [15]. To introduce some absorption in the modulator, radio signal

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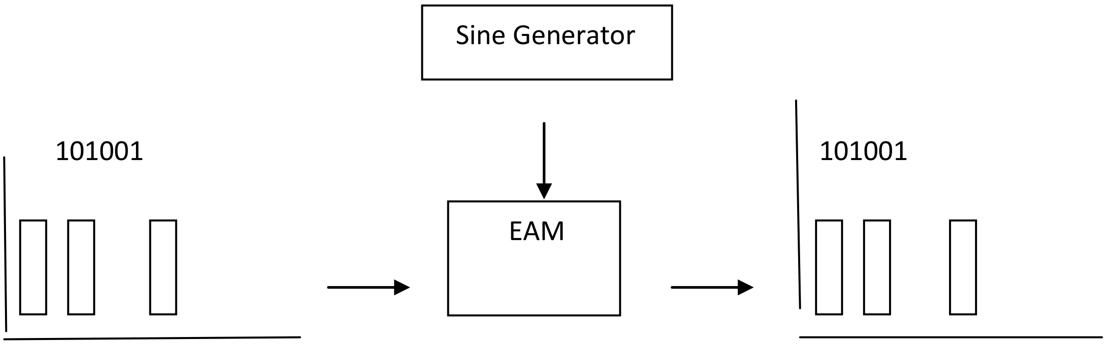
from sine generator is applied. Fundamentally, EAM worked on modulation of percentage of photons absorbed in an optical waveguide by varying the strength of electric field applied across the waveguide. Fig. 2 shows the basic principle of operation for an EAM as an optical wavelength converter, where wavelength conversion can be achieved through the cross absorption of the signal using input signal CW laser and radio signal from sine generator.



Input signal output signal

Fig. 2 Basic principle of EAM as wavelength converter

The output of converted signal dependent on various factors such as the modulator chirp. The average optical power transmitted and extinction ratio of the device. The mathematical behavior of optical output signal power (16) i.e. Eout(t) can be describe as:

$$\mathbf{Eout(t) = Ein\ (t)\ T(t)}\ e^{j\Phi(t)}$$

Where Ein(t) is the input signal and $\Phi(t)$ define as phase variation and T(t) stands for absolute value of transmission function. The phase variations result from refractive index variation that lead to chirp on output signal. This can also be witten as:

$$\mathbf{Eout(t) = Ein\ (t)}.\sqrt{Mod\ (t)}.\ \mathbf{exp}\ (j\alpha/2, In(Mod(t)))$$

Where Eout is the output optical power, α is the chirp factor and Mod(t) is defined as:

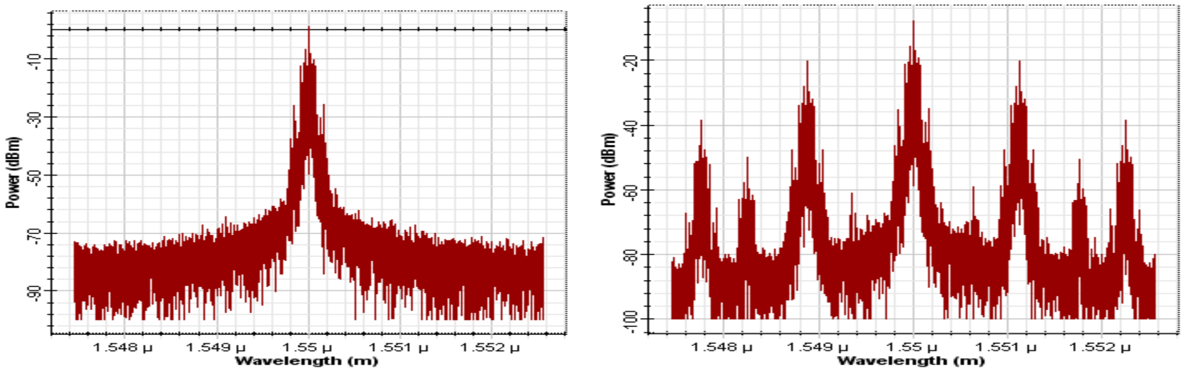
Mod (t) = (1-MI) + MI. modulation(t)

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

TABLE I. Parameters used in simulation

Description	Values
Extinction ratio of Mach-Zender Modulator	30 dB
Input Wavelength	1550 nm
EAM modulation index	0.60- 0.95
Sine Generator frequency	500 GHz
Receiver Responsivity	1 A/W

3. Results and Discussion



(a) (b)

Fig. 3 Optical spectrum of signal after (a) MZM (b) EAM

Fig. 3(a) represents the spectrum of original signal after passing through the Mach-Zender Interferometer with center wavelength at 1550 nm. Fig. 3(b) portrays the spectrum of signal after passing through EAM and we observe the multiwavelngth conversions due to the nonlinear effect of EAM. In this simulation setup we observed the performance of converted wavelength at 1548.9 nm and 1551.1 nm because the rest of converted wavelength performance is very poor. However, results are obtained at data rates such as 1 Gbps, 5Gbps and 10 Gbps with filter bandwidth 2 GHz, 10GHz and 20 GHz respectively.

The main elements forming the structure of simulation model as shown in Fig.1. The output of Simulation model determines the behavior for an EAM with the variation of input power, modulation index, line width, Q – factor caused by change in absorption characteristics. Typical values of parameter used in simulation is shown in Table 1. Fig. 4 and Fig. 5 represent the Quality of Up converted and down converted wavelength signal at 1551.1 nm and 1548.9 nm respectively at different data rate of 1 Gbps, 5 Gbps and 10 Gbps. Here variation in input signal power was applied using sweep generator. As we increase the input signal power at different data rate the quality of converted signal also increases and hence the system performance also improves. Here the quality of converted signal is increases as we increases the input signal power because as we increase the power of input signal the XAM effect in the EAM will be more stronger so the quality of converted signal becomes bigger gradually.

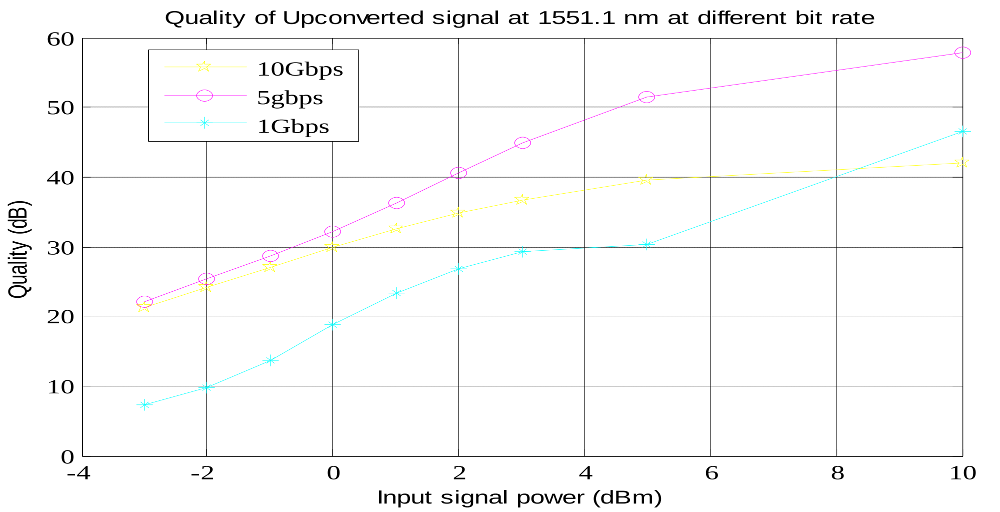


Fig. 4 Quality of Upconverted signal at 1551.1 nm at different bit rate

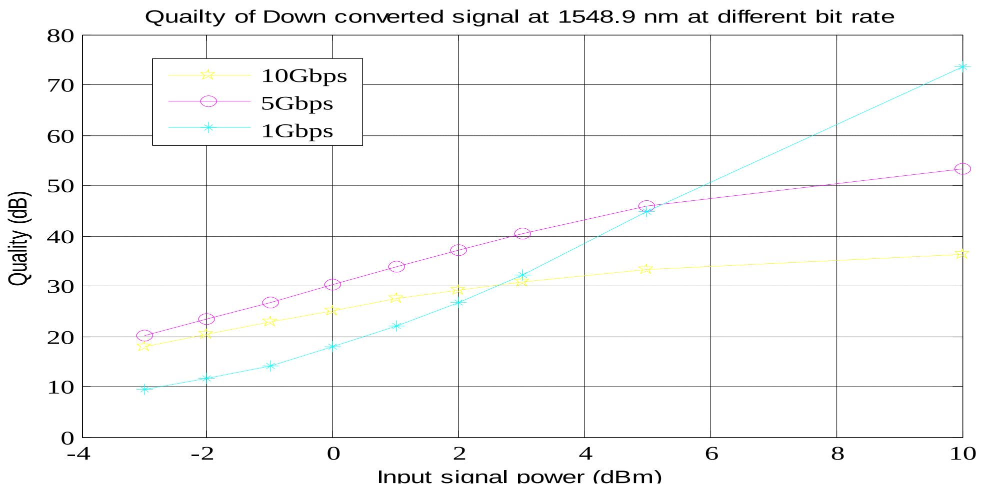


Fig. 5 Quality of Downconverted signal at 1548.9 nm at different bit rate

The graph of up converted and down converted wavelength signal power with respect to input power at different data rate is shown in Fig. 6 and Fig. 7 respectively. It has been observed that for both up converted and down converted wavelength as the input signal power increases, the converted signal power goes on increases.

Fig. 8 demonstrates the effect of line width variation on Q - factor for the values of receiver responsivity for wavelength as given in Table1. A range of line width from 0 – 500 have been used to observe the effect on Q – factor for bit rate of 10 Gbps. At the low value of line width the output spectrum become more broaden due to XAM. It has been clear from Fig. 8 that as we increase the value of line width the quality of converted signal goes on decreasing for both the up converted and down converted signal. From the simulation it has been observed that as we increase the value of modulation index (0.6 to 0.95) more light linked to output, as a result of which there is an improvement of quality of converted signal, because value of output power directly depends upon modulation index and varies linearly with the modulation index.

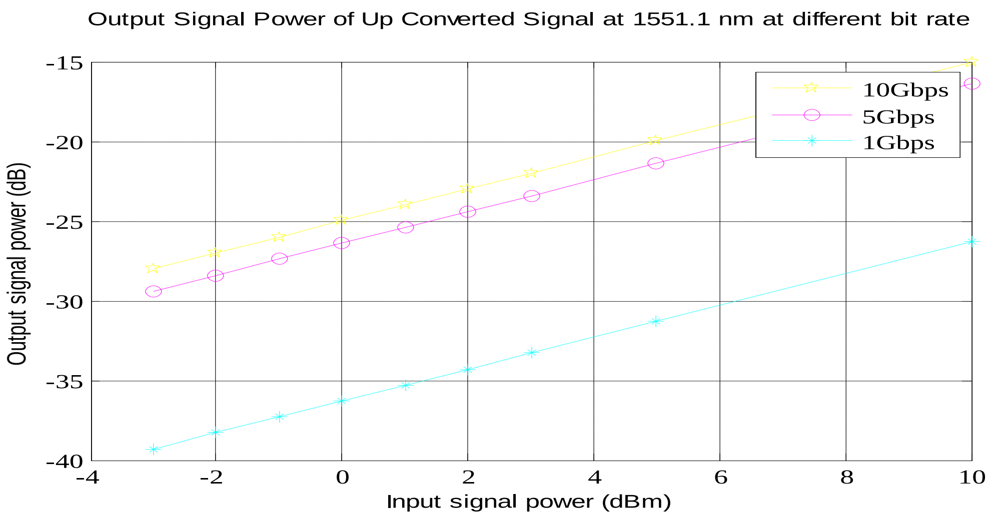


Fig. 6 Output Signal Power of Upconverted signal at 1551.1 nm at different bit rate

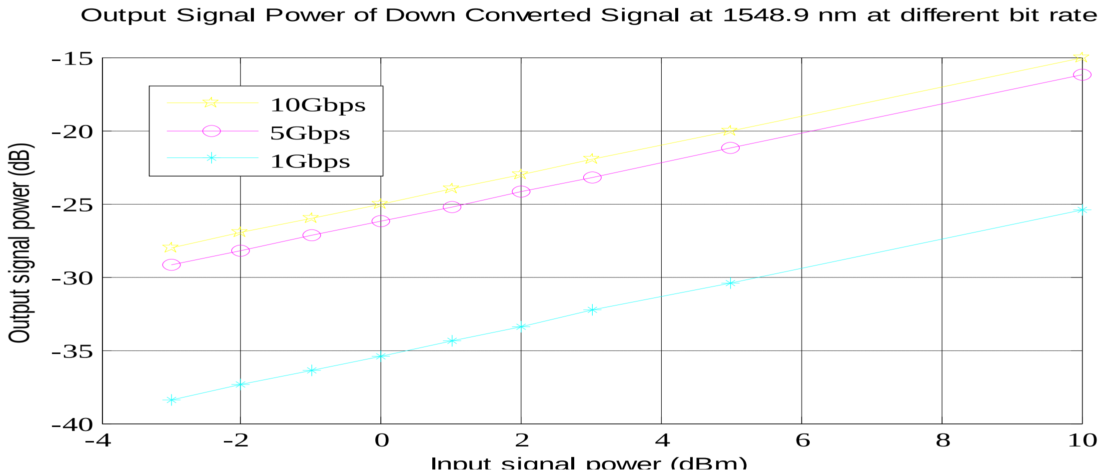


Fig. 7 Output Signal Power of Downconverted signal at 1548.9 nm at different bit rate

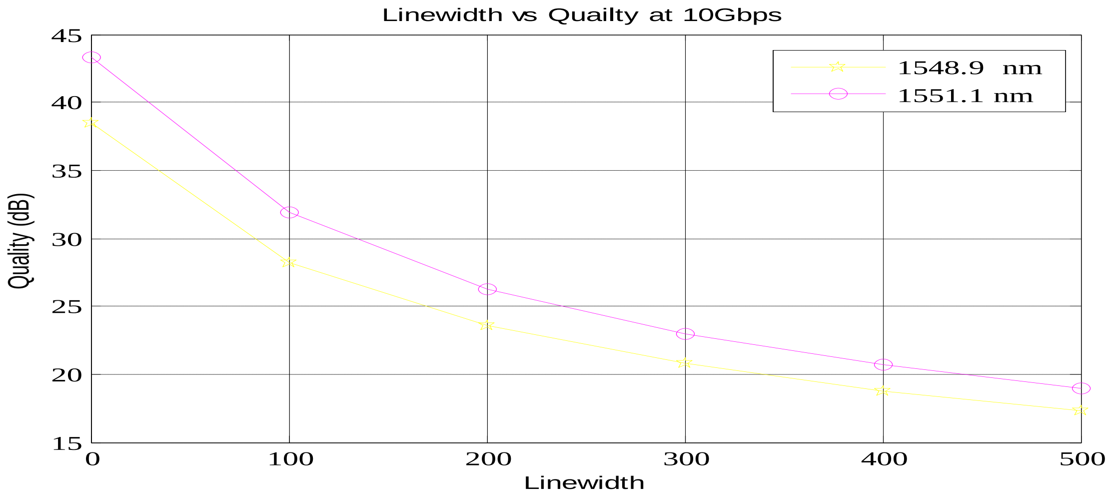


Fig. 8 Linewidth Vs Quailty at 10 Gbps

4. Conclusion

We have demonstrated simulation setup of cost effective EAM based wavelength conversion which consist of sine generator and laser source as an input by eradicate the requirement of extra pump source. For the high performance of wavelength conversion, it is important to select the high value of modulation index and better performance of system reported at higher modulation index value i.e. 0.95. From the output of wavelength conversion the best result achieved at 1551.1 nm and 1548.9 nm wavelengths having -3 dBm to 10 dBm input signal power and data rate is varying from 1Gbps, 5 Gbps and 10 Gbps. As we increase the input signal power the corresponding output signal power of converted signal also increases due to increasing transmission increment induced by XAM effect. Here the quality of converted signal is increases as we increases the input signal power because as we increase the power of input signal the XAM effect in the EAM will be more stronger so the quality of converted signal becomes bigger gradually. Hence we conclude that the overall performance of EAM based wavelength converter can be enhanced by applying high input power and low value of line width such as 0 to 10 MHz.

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