All Optical Wavelength Conversion Based On Four Wave Mixing in Optical Fiber

Surinder Singh, Gursewak Singh Lovkesh

***Abstract*—**We have designed wavelength conversion based on four wave mixing in an optical fiber at 10 Gb/s. The power of converted signal increases with increase in signal power. The converted signal power is investigated as a function of input signal power and pump power. On comparison of converted signal power at different value of input signal power, we observe that best converted signal power is obtained at -2 dBm input signal power for both up conversion as well as for down conversion. Further, FWM efficiency, quality factor is observed for increase in input signal power and optical fiber length.

***Keywords*—**FWM, Optical fiber, Quality, Wavelength Converter.

I. Introduction

When a high power optical signal passes through an optical fiber, it changes the refractive index of an optical fiber. This is a nonlinear effect, in which optical signal power changes the properties of medium through which it passes. Four wave mixing is a type of nonlinear effect, this effect occurs when light of two or more wavelengths is launched in to an optical fiber [1], [3]. The launch of light of different wavelengths produces a signal at new wavelength. On basis of parameters of optical fiber one, two or more signals can be obtained, which can be called as up converted signal or down converted signal. Four wave mixing is commonly avoided in wavelength division multiplexing (WDM) communication but it can be useful for some applications. Four wave mixing has been used to be give the transmission of data at new wavelength, which is obtained as a result of interaction of given set of wavelengths. The problem is created if equal channel spacing is used between given set of wavelengths. However, this problem is overcome by unequal channel spacing [1]. An optical amplifier is used to increase the transmission distance, which an optical signal can cover with sufficient value of power. Several techniques have been proposed by potential researchers to achieve wavelength conversion [1]-[8]. The straight forward solution is an opto electronic converter consists of an electrical detector and optical transmitter for transmission and converter to generate new wavelength of incoming optical signal.

The disadvantages of the opto-electronic converter are their complexity and large power consumption. This directs the interest to all optical wavelength converters which enable direct translation of the information for the incoming wavelength to a new wavelength without entering in the electrical domain. All optical wavelength converter based on semiconductor optical amplifiers (SOAs) used various effects such as the cross gain modulation (XGM) mode or the cross phase modulation (XPM) mode, cross polarization modulation mode (XPolM) and four wave mixing (FWM) [2] .

In a four-wave mixing–based converter [3], if v_1 and v_2 are the frequencies of input signal and the converted signal, the pump frequency chosen is such that

$$v_p = (v_1 + v_2)/2 \quad (1)$$

Durhuus et al. [2] reported analysis of XGM and XPM wavelength conversions at 10 Gb/s. Also increased bandwidths are expected for SOA that tolerate larger bias currents and have higher confinement factor. Experimental results for MZI Semiconductor optical amplifier converters give penalty free operation at 5 Gb/s. Due to low confinement factor, the conversion speed is restricted to 5 Gb/s for the investigated device but theoretical studies show that 40 Gb/s is possible with optimized SOA.

Lacey et al. [4] proposed all optical 1310 nm to 1550 nm wavelength converter by using non-linear polarization rotation in a single semiconductor optical amplifier at bit rate of 10 Gb/s. Fu et al. [5] demonstrated wavelength conversion of 10 Gb/s with 2R regeneration for whole C band by using nonlinear polarization rotation with linear polarization maintenance of wavelength conversion signal. Nesset et al. [6] described wavelength converter with semiconductor optical amplifier nonlinearities XGM, XPM, cross polarization modulation (XPolM) by adding an extra delay line. Yates et al. [7] reported the wavelength converters in dynamically reconfigurable WDM networks. There are less work has been reported for design of wavelength conversion using optical fiber.

II. System Setup

In this model data is transmitted at 10 Gb/s through an optical fiber. Input signal is modulated with non-return to zero (NRZ) format. The modulated signal and pump signal are transmitted through an optical fiber. Two new signals are obtained at output of an optical fiber due to interaction of signals with fiber nonlinearities.

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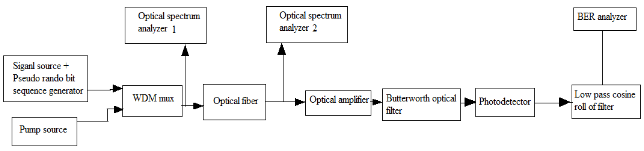

Fig. 1 10 Gb/s optical wavelength conversion set up

As shown in Fig. 1, the setup is consisting of transmitter section, receiver section and channel. The transmitter section consists of electrical driver, data source, laser and external Mach Zehnder modulator. The function of data source is to generate signal of 10 Gb/s with pseudo random sequence. The electrical driver converts logical input signal in to electrical signal. The continuous wave (CW) laser sources generate laser beams at 1550 nm and 1552 nm. The signals from laser source and data source are fed to Mach Zahnder modulator, where information signal is modulated by laser source. The simulation set up of an optical fiber is shown in Fig. 1 for different dispersion parameters and signal powers. The modulated signal and laser signal are given to a WDM multiplexer. The output of multiplexer is applied to an optical fiber then due to nonlinear effects at the output of fiber two new signals are produced at different wavelengths. These signals are amplified by using an erbium doped fiber amplifier with fix gain, so that signals can be properly received at the receiver. The receiver section consists of an optical filter, photodetector, low pas filter and bit error rate (BER) analyzer. The function of an 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. Low pass filter is used to pass only low frequency of electrical signals and reject high frequency signals. The BER analyzer is used to display quality factor and bit error rate of signal. An optical signal is transmitted and its performance is evaluated for different values of dispersion parameters and signal powers. The setup is repeated by varying parameters of an optical fiber and signal strength is measured for different iterations. Different results like eye diagram, quality factor and BER are obtained, which calculate best parameters of an optical fiber. Optical spectrum analyzer and BER analyzer are used to measure power of signal and quality factor, bit error rate of signal respectively. The parameters for Mach Zehnder modulator are shown in Table I:

TABLE I
PARAMETERS OF MACH ZEHNDER

Extinction ratio	30 dB
Symmetry factor	-1

The WDM multiplexer is used to combine optical signals; its various parameters are shown in Table II:

TABLE II
PARAMETERS OF WDM MULTIPLEXER

Bandwidth	20 GHz
Depth	100 dB
Filter type	Bessel
Order	3

A single mode optical fiber is used to transmit the optical signal; its various parameters are shown in Table III.

TABLE III
PARAMETERS OF OPTICAL FIBER

Reference wavelength	1550 nm
Length	8 km
Dispersion	-50 ps/nm/km
Dispersion slope	-0.01 ps/nm^2/km
Differential group delay	0.5 ps/km
Effective area	50 μm^2
Attenuation	0.2 dB/km

As shown in Fig. 1, two optical signals are applied at 1550 nm and 1552 nm. The beating of these two signal produces four wave mixing effect and generate two new signals at 1554 nm and 1548 nm, called as up converted signal and down converted signal respectively. An optical filter is used to extract these signals, so that signals can be properly received. Two optical filters of 20 GHz tuned at different frequencies are used to get the converted signals.

III. RESULTS AND DISCUSSION

The variable bandwidth simulations are performed for setup as shown in Fig. 1. The two optical signals are applied at 1550 nm and 1552 nm are generate two new signals 1554 nm and 1548 nm due to effect of four wave mixing which called up converted signal and down converted signal respectively.

A. Down Wavelength Converter

The graph of converted signal power with respect to input power with variations in pump power is shown in Fig. 2. It is observed that as the input signal power increases the converted signal power goes on increasing. Fig. 3 shows the quality of converted signal variation with respect to applied input signal power for variation of pump power. It is observed that quality of signal goes on increasing with increase in input signal power.

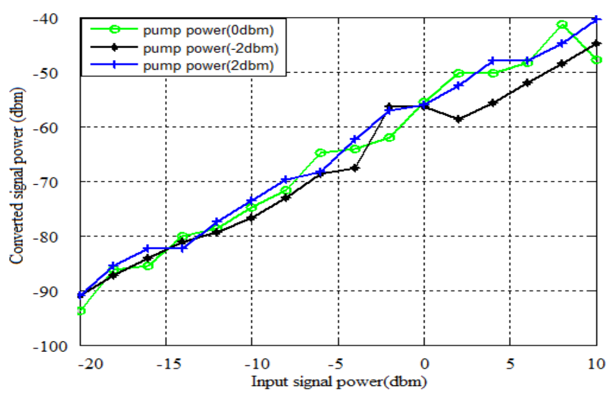

Fig. 2 Converted signal power versus input signal power of down wavelength converter

But with increase in pump power, the quality of signal drop without variation in converted power. This drops in quality due to saturation of signal in optical fiber. The four wave mixing conversion efficiency is given as the converted power at optical fiber output, divided by signal power at the optical fiber input. The plot between four wave mixing efficiency and input signal power is shown in Fig. 4. The FWM efficiency goes on increasing with increase in signal input power and pump power. The variation of quality factor with increase in length of optical fiber is shown in Fig. 5. The quality factor of signal goes on increasing with increase in length of fiber for fixed input signal power of -2 dBm. At optical fiber length of 11 km, there is fall in quality of signal for all pump power. It is observed that at -2 dBm pump power shows better quality as compared to higher pump power but power penalty occurs for lower the pump power.

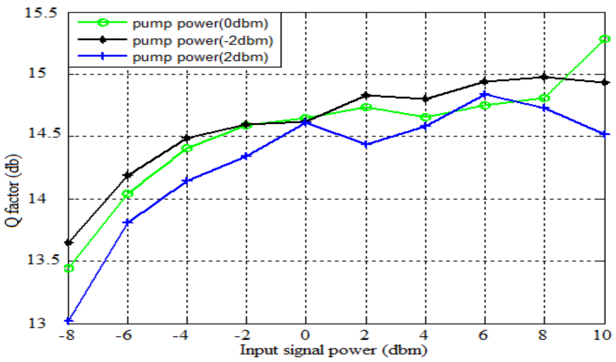

Fig. 3 Converted signal quality versus input signal power of down wavelength converter

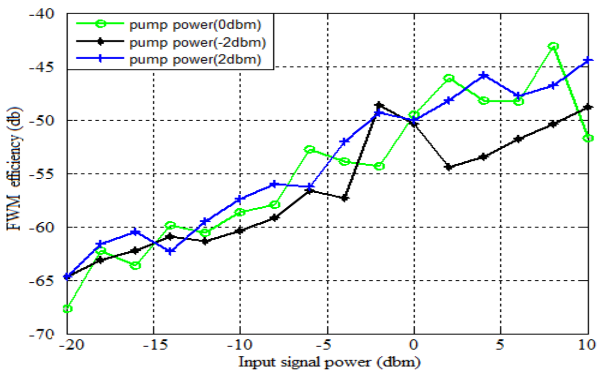

Fig. 4 FWM efficiency versus input signal power of down wavelength converter

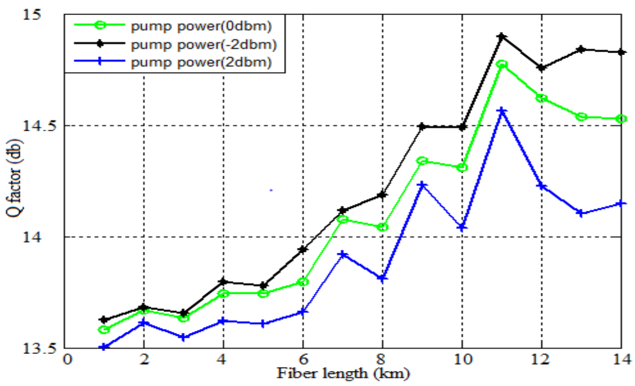

Fig. 5 Q-factor versus fiber length of down wavelength converter

B. Up Wavelength Converter

The graph of up wavelength converted signal power with respect to input power with variations in pump power is shown in Fig. 6. It is observed that as the input signal power increases, the converted signal power goes on increases up to 10 dBm. Fig. 7 shows the quality of converted signal variation with respect to applied input signal power for variation of pump power. It is observed that quality of signal goes on increasing with increase in input signal power. It is also observed that up wavelength converted signal has belter quality as compared to down wavelength converted signal. The graph between four wave mixing efficiency and input signal power is shown in Fig. 8. The FWM efficiency goes on decreasing with increase in signal input power and pump power which agrees with [8]. It is also observed that higher FWM efficiency is reported for high value of pump power signal.

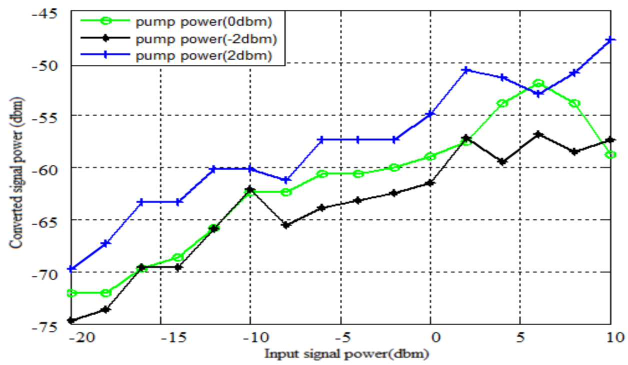

Fig. 6 Converted signal power versus input signal power of up wavelength converter

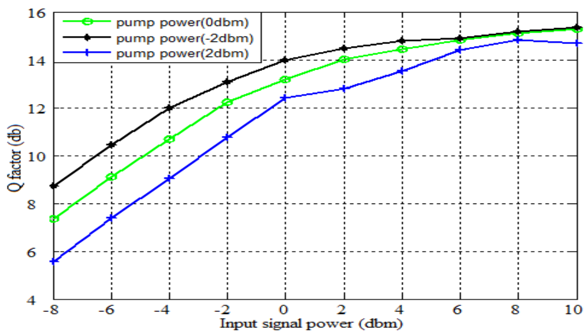

Fig. 7 Converted signal quality versus input signal power of up wavelength converter

The variation of quality factor with increase in length of optical fiber is shown in Fig. 9. The quality factor of signal goes on decreasing with increase in length of fiber for fixed input signal power of -2 dBm. It is observed that at -2 dBm pump power shows better quality as compared to higher pump power but power penalty occurs for lower the pump power.

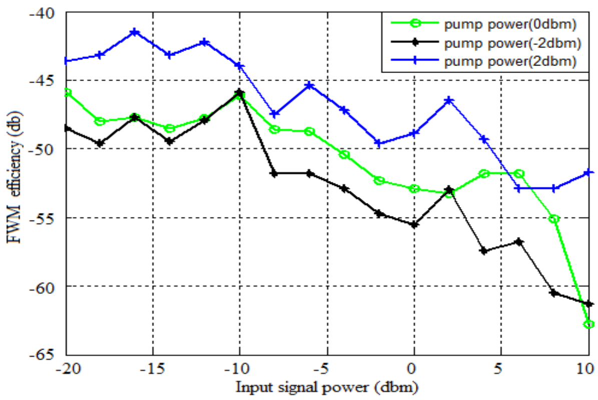

Fig. 8 FWM efficiency versus input signal power of up wavelength converter

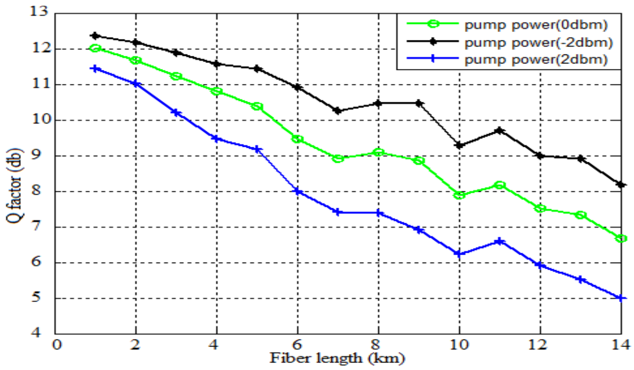

Fig. 9 Q-factor versus fiber length of up wavelength converter

IV. Conclusion

We demonstrate all optical wavelength converter based on single mode optical fiber. There is large difference between the power of up converted signal and down converted signal at low value of input signal power. As we increase the power of input signal, the difference between the power of up converted signal and down converted start to decrease. At -2 dBm down converted signal power comes close to up converted signal power. The highest value of converted signal is also obtained at -2 dBm for both signals. This conversion technique is power efficient since value of pump power is very small. The manufacturing of this optical fiber lead towards the expandability of optical networks.

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