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# *Conversion of Optical Wavelength Based on Four Wave Mixing in Optical Fiber*

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**Abstract**

*In an optical cable operating at 10 Gb/s, we have developed a wavelength conversion method based on four wave mixing. With an increase in signal strength, the converted signal's power rises. Investigated in relation to input signal power and pump power is the converted signal power. The best converted signal power is obtained at -2 dBm input signal power for both up conversion and down conversion, according to a comparison of converted signal power at various input signal power values. Furthermore, as the input signal amplitude and optical fibre length grow, the FWM efficiency and quality factor increase.*

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

## INTRODUCTION

A high power optical signal modifies an optical fibre's refractive index as it travels through the fiber. This is a nonlinear effect in which the properties of the medium are altered by the optical signal power. When light with two or more wavelengths is fired into an optical fibre, a nonlinear process known as four wave mixing takes place [1], [3]. A signal at a new wavelength is produced when light of various wavelengths is launched. Based on the optical fiber's properties, two or more signals, known as up- or down converted signals, can be obtained. Although it can be helpful in some situations, four-wave mixing is often avoided in wavelength division multiplexing (WDM) communication. In order to transmit data at a new wavelength, which is produced by the interaction of a given set of wavelengths, four-wave mixing has been utilised. If equal channel spacing is employed between a given set of wavelengths, the issue arises. Uneven channel spacing, however, solves this issue [1]. An optical amplifier is used to extend the range that an optical signal can travel when powered sufficiently. Potential researchers have suggested a number of methods to achieve wavelength conversion [1]–[8]. An opto electronic converter is a simple solution that comprises an electrical detector, an optical transmitter, and a converter to create a new wavelength of an incoming optical signal.

Opto-electronic converters' drawbacks include their complexity and high power requirements. This draws attention to all optical wavelength converters that allow for direct wavelength translation, i.e., information from one wavelength to another without involving the electrical domain. All optical wavelength converters based on semiconductor optical amplifiers (SOAs) used a variety of effects, including four wave mixing (FWM), cross polarisation modulation (XPolM), cross gain modulation (XGM), and cross phase modulation (XPM) [2].

In a four-wave mixing–based converter [3], if ν1 and ν2 are the frequencies of input signal and the converted signal, the pump frequency chosen is such that

$$\nu\nu_{pp} = (\nu\nu 1 + \nu\nu 2)/2 \qquad (1)$$

Analysis of XGM and XPM wavelength conversions at 10 Gb/s was reported by Durhuus et al. [2]. For SOAs that tolerate higher bias currents and have higher confinement factors, increased bandwidths are also anticipated. The experimental results for the optical amplifier converters from MZI Semiconductor allow for penalty-free operation at 5 Gb/s. The conversion speed is limited to 5 GB/s for the researched device due to a poor confinement factor; theoretical studies indicate that 40 GB/s is feasible with an optimised 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.

**System Setup**

In this concept, data is sent across an optical cable at 10 GB/s. The input signal is modulated using the NRZ format, or non-return to zero. Through an optical fibre, the modulated signal and pump signal are sent. Due to the interaction between the signals and the fibre nonlinearities, two additional signals are produced at the optical fibre's output. The setup is comprised of a transmitter part, a reception section, and a channel, as shown in Fig. 1. Electrical driver, data source, laser, and an external Mach Zehnder modulator make up the transmitter component. The purpose of the data source is to produce a 10 Gb/s pseudo-random signal. Electrical input signals are transformed into electrical signals by the electrical driver. The laser sources produce laser beams at 1550 nm and 1552 nm using continuous wave (CW) technology. The signals from the data source and the laser source are supplied into the Mach Zahnder modulator, where the laser source modulates the information signal. Fig. 1 depicts the simulation setup for an optical fibre for various dispersion parameters and signal strengths. A WDM multiplexer receives both the laser signal and the modulated signal. When a multiplexer's output is applied to an optical fibre, two additional signals at various wavelengths are formed as a result of nonlinear effects at the fibre's output. In order for these signals to be amplified and properly received at the receiver, an erbium doped fibre amplifier with fixed gain is used. An optical filter, photodetector, low pass filter, and bit error rate (BER) analyzer make up the receiver part. An optical filter's job is to pick out the intended band of signals and block out the unwanted ones.

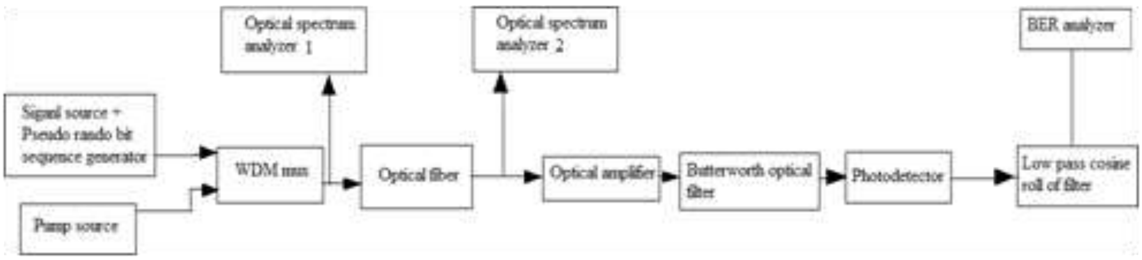


*Fig. 1 10 Gb/s optical wavelength conversion set up*

A photodetector is used to transform an optical signal into an electrical signal. Only low frequency electrical signals that are being rejected are those that are being passed by a low pass filter. The bit error rate and quality factor of the signal are displayed by the BER analyzer. When transmitting an optical signal, its performance is measured for various dispersion parameters and signal strength values. Signal strength is monitored for each iteration of the setup when the optical fibre's parameters are changed. The optimal parameters for an optical fibre are calculated using many outcomes, including eye diagrams, quality factors, and BER. The strength of the signal and the quality factor, or bit error rate, of the signal are measured, respectively, using optical spectrum analyzers and BER analyzers.

**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 nmLength |
| Dispersion | -50 ps/nm/km |
| Dispersion slope | -0.01 ps/nm$^2$/kmDifferential group delay |
| Attenuation | 0.2 dB/km |
| Reference wavelength | 1550 nmLength |
| Dispersion | -50 ps/nm/km |
| Dispersion slope | -0.01 ps/nm$^2$/kmDifferential group delay |

Two optical signals are applied at 1550 nm and 1552 nm, as seen in Fig. 1. The beating of these two signals results in a four-wave mixing effect and creates two new signals, referred to as up converted signals and down converted signals, respectively, at 1554 nm and 1548 nm. These signals are extracted using an optical filter so that signals can be effectively received. To obtain the transformed signals, two 20 GHz optical filters adjusted at separate frequencies are required.

## Results And Discussion

The setup for the variable bandwidth simulations is depicted in Fig. 1. Due to the result of four wave mixing, which is referred to as an "up converted signal" and "down converted signal," respectively, the two optical signals applied at 1550 nm and 1552 nm form two new signals at 1554 nm and 1548 nm.

## Down Wavelength Converter

Fig. 2 depicts the converted signal power vs input power with pump power fluctuations as a graph. It has been found that when the input signal power rises, so too does the transformed signal power. The quality of the converted signal variation for changed pump power is shown in Fig. 3 with respect to applied input signal power. It has been found that as input signal power increases, signal quality also does so.

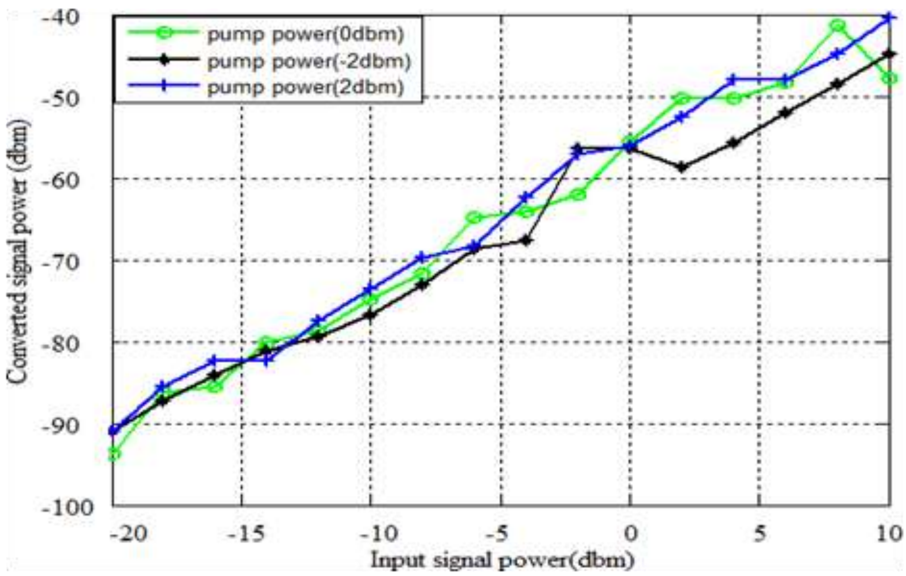


*Fig. 2 Converted signal power versus input signal power of down wavelength converter*

However, as pump power is increased, the quality of the signal declines without changing the converted power. This quality decline is brought on by signal saturation in the optical fiber. When signal power at the optical fibre input is divided by converted power at the optical fibre output, the four wave mixing conversion efficiency is given. Figure 4 depicts the relationship between four wave mixing efficiency and input signal power. With a rise in signal input power and pump power, FWM efficiency keeps rising. Figure 5 illustrates how the quality factor changes as the length of the optical cable increases. For a fixed input signal power of -2 dBm, the quality factor of the signal continues to rise as the length of the fibre increases.

For all pump powers, there is a decline in signal quality at an optical fibre length of 11 km. When compared to higher pump powers, it has been found that pump power at -2 dBm exhibits better quality, however, lower pump powers incur a power penalty.

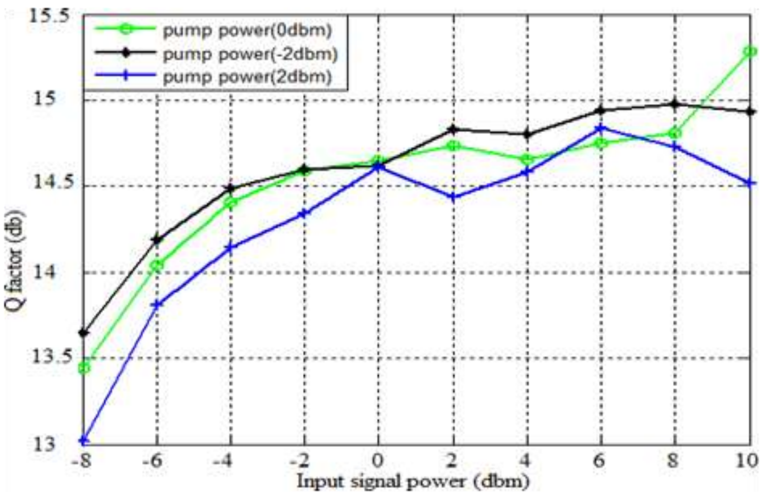


***Fig. 3 Converted signal quality versus input signal power of down wavelength converter***

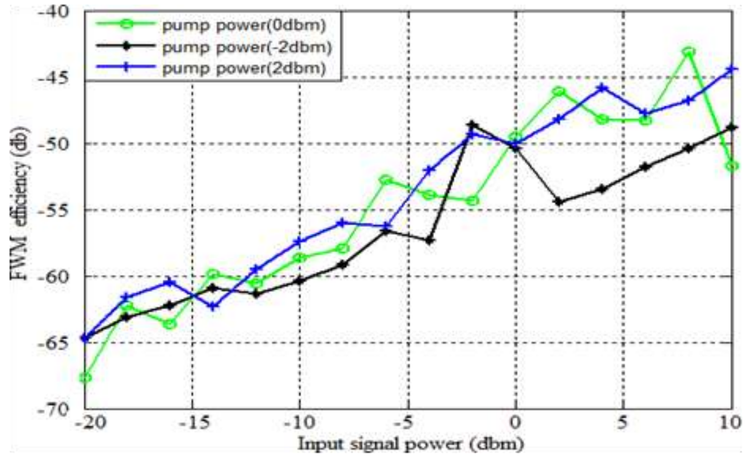


*Fig. 4 FWM efficiency versus input signal power of down wavelength converter*

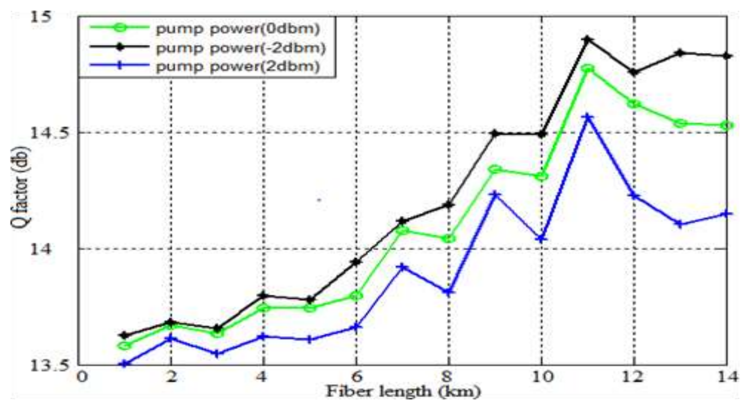


*Fig. 5 Q-factor versus fiber length of down wavelength converter*

## Up Wavelength Converter

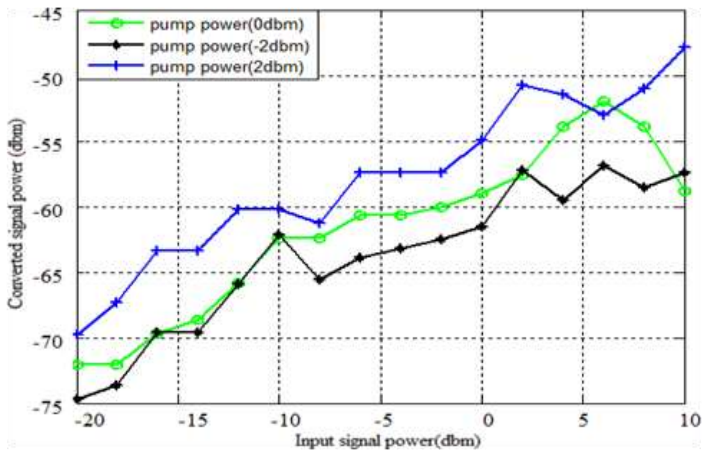


*Fig. 6 Converted signal power versus input signal power of up wavelength converter*

Figure 6 displays the up-wavelength converted signal power versus input power with pump power variations. It has been noted that the converted signal power increases up to 10 dBm as the input signal power increases. The quality of the converted signal variation for changed pump power is shown in Fig. 7 with respect to applied input signal power. It has been found that as input signal power increases, signal quality also does so. Additionally, it has been found that up-wavelength converted signals have better quality than down-wavelength converted signals. Figure 8 depicts the relationship between four wave mixing efficiency and input signal power. According to [8,] the FWM efficiency continues to decline as signal input power and pump power rise. Additionally, it is noted that reports of greater FWM efficiency pertain to pump power signals with high values. Figure 9

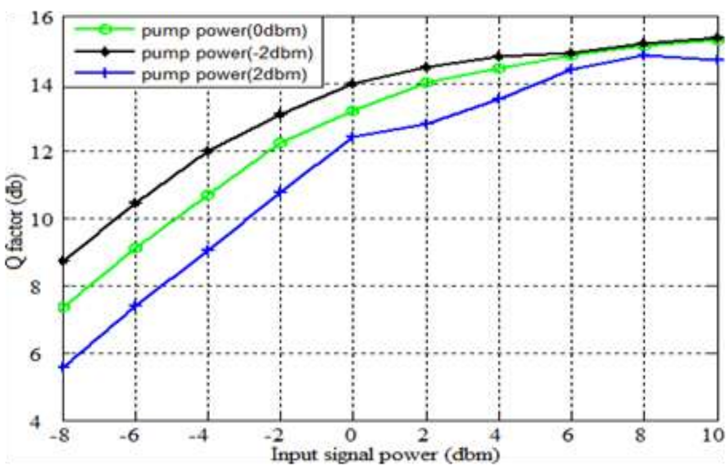


***Fig. 7: Converted signal quality versus input signal power of up wavelength converter***

illustrates how the quality factor changes as the length of the optical cable increases. For a fixed input signal power of -2 dBm, the quality factor of the signal continues to decline as the length of the fibre increases. When compared to higher pump powers, it has been found that pump power at -2 dBm exhibits better quality; however, lower pump powers incur a power penalty.

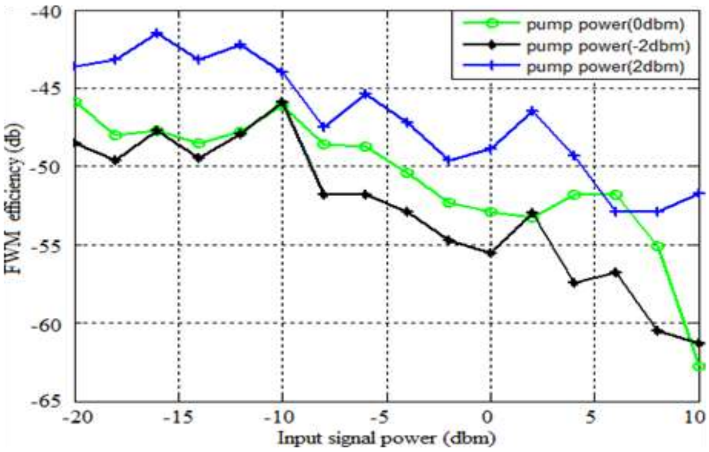


*Fig. 8 FWM efficiency versus input signal power of up wavelength converter*

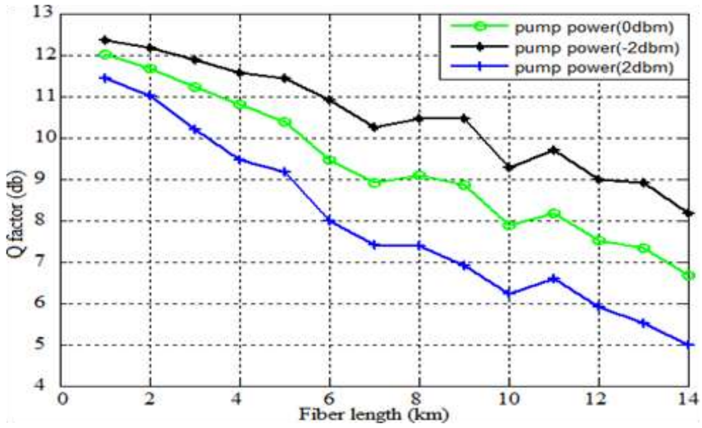


*Fig. 9 Q-factor versus fiber length of up wavelength converter*

## CONCLUSION

We use single mode optical fibre to demonstrate all optical wavelength converters. At low input signal power levels, there is a significant difference between the power of an up converted signal and a down converted signal. The power difference between the up-converted signal and the down-converted signal starts to decrease as the input signal power increases. Down converted signal power approaches up converted signal power at -2 dBm. For both signals, the highest converted signal value is also attained at -2 dBm. Since the value of the pump power is so low, this conversion approach is incredibly energy efficient. The potential for optical networks to grow was made possible by the production of this optical fibre.

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