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**A. J. UTRERAS TELLO[1], G. L. LICENKO[2], V. H. REYES CIFUENTES[1], R. I. MENA VILLACIS[1], E. S. JARAMILLO PINOS[1]**

# OPTICAL WAVELENGTH CONVERTERS IN FIBER OPTICAL NETWORKS

*[1]Escuela Politécnica Nacional, Ecuador*
*[2]Vinnitsia National Technical University, Ukraine*

**Abstract**. Optical Networks often use a wavelength converter as part of a switching system to improve their networks. Wavelength conversion is defined as a process by which the wavelength of the transmitted signal is changed without altering the data carried by the signal. The device that performs this function is usually called a wavelength converter but it is also referred to as a wavelength (or frequency) changer, shifter or translator. It is termed an up-converter when the converted signal wavelength is longer than the original signal wavelength and it is called a down-converter if the converted signal wavelength is shorter than the original signal wavelength. A wavelength converter should be capable of receiving an incoming signal at any wavelength (i.e. a variable wavelength) at the input port and must produce the converted signal at a particular wavelength (i.e. a fixed wavelength) at the output port. Therefore the input/output (I/O) ports of the converter must possess the capability of a variable input–fixed output (VIFO) converter and the majority of the optical switching networks use this type of device

**Keywords:** Wavelength converter, Optical Switching, Optical Networks, switching, Mach Zender.

## INTRODUCTION

In a WDM network, it is possible to route data to its destination based on its wavelength. The use of wavelengths for routing data is called wavelength routing. A network that uses this technique is known as a wavelength-routed network which consists of routing switches (or routing nodes) interconnected by fiber optic cables. WDM uses the large bandwidth (THz) of a single-mode optical fiber while providing channels with bandwidths (1-10 Gbps) that are compatible with current electronic processing speeds.

The objective of a wavelength converter is to convert the wavelength of an input signal that carries data to an output wavelength possibly different from the N wavelengths of the system corresponding to the N channels available. [1]

An ideal wavelength converter has the following characteristics [2]:
- Transparency at binary rate and signal formats;
- Fast setup of output wavelength;
- Conversion to shorter and longer wavelengths;
- Moderate levels of power input (input power less than – 10dbm for a SOA converter) [3];
- Maintenance of a same wavelength as input and output (no conversion);
- Insensitivity to polarization of the input signal;
- Simple implementation

## WAVELENGTH CONVERSION TECHNIQUES

Optical/Electronical-wavelength conversion (o/e conversion): In this method, the optical signal is first converted to the electronic domain using a photo detector (called R in Figure 1). The electronic bit stream is stored in a buffer (FIFO). The electronic signal is then used to power the entrance of a tunable laser (T) to the desired output wave length.

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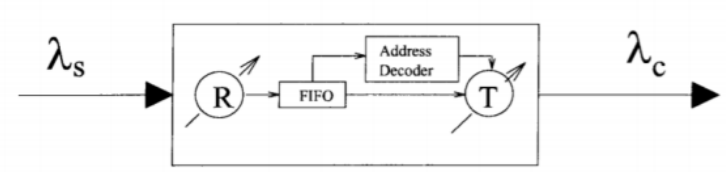

Fig 1. O / E wavelength converter

All-optical wavelength conversion: In this method, the signal is kept in the optical domain during the whole process of conversion.

Conversion of wavelength by wave-mixing: The wave-mixing comes from a non-linear optical response of a medium where there is more than one wavelength. By controlling the response of a certain order of the system, a conversion towards the desired wavelength is obtained. The wave-mixture keeps the information of phase and amplitude, offering a strict transparency. There are two techniques: FWM (Four wave mixing) and DFG (Difference sequence generation).

Wavelength conversion through cross modulation: this technique uses an optical-active-semiconductor devices such as a semiconductor optical amplifier, SOA (two modes included: cross gain modulation, XGM and cross phase modulation XPM), and lasers.

Although many schemes have been proposed and demonstrated for wavelength conversion, none is completely transparent to the signal format and they have significant limitations. Therefore, the capacity and nature of the network can be determined, to some extent, by the schemes implemented for wavelength conversion. [4]

During the process of XGM and XPM another phenomenon, namely that of instantaneous frequency variation, occurs which is commonly referred to as frequency (or wavelength) chirp. It is defined as the deviation in the emission frequency with respect to time when a laser is driven by a time-varying current source (i.e. intensity-modulated digital signal). Since refractive index is related to frequency then a variation in the refractive index produces a variation in frequency at each instant. This chirp is commonly observed in the intensity-modulated converted probe signal affecting the leading and trailing edges Wavelength conversion 587 Figure 10.27 Cross-phase modulation (XPM) wavelength converter using semiconductor optical amplifiers (SOAs) in a Mach–Zehnder interferometer (MZI) arrangement: (a) copropagating scheme; (b) counterpropagating scheme OPTF_C10.qxd 8/11/09 11:47 AM Page 587 of the pulses when the refractive index varies suddenly due to an instantaneous change in pulse amplitude. Figure 10.28 illustrates the concept of frequency chirp associated with the intensity-modulated signal shown in the top diagram, while the diagram underneath depicts the corresponding frequency chirp at the leading and trailing edges. When frequency chirp shifts the optical frequency towards the shorter wavelength it is known as blue shift, while a shift of optical frequency towards the longer wavelength is called red shift. The sign of the chirp is said to be positive when the leading edge of the pulse is red shifted in relation to the central wavelength and the trailing edge is blue shifted, and when the shifts are opposite to the foregoing then the sign of chirp will be negative. Hence Figure 10.28 displays a positive chirp condition

The relationship between the frequency chirp $\Delta f$ and the phase of the converted signal $\varphi$ is given by:

$$\Delta f(t) = -\frac{1}{2\pi}\frac{d\phi(t)}{dt}$$

## RESULTS

To understand the effects of a wavelength converter we citated semiconductor optical amplifier (SOA) operating at a signal wavelength of 1.55 μm produces an output signal power of 10 mW with an input signal power of 0.5 mW. The differential refractive index of the device is −1.2 × 10−26 m3 , the linewidth enhancement factor is −1.0 and the input signal power variation is 0.01 μm. Calculate: (a) the frequency chirp variation at the output signal; (b) the differential gain required in order for the device to operate at the same signal wavelength. Solution: The frequency chirp Δf can be obtained by combining:

$$\begin{aligned}\Delta f(t) &= -\frac{\alpha}{4\pi}\frac{1}{P_{\text{in}}(t)}\frac{\mathrm{d}P_{\text{in}}(t)}{\mathrm{d}t}\\ &= -\frac{-1}{4\times 3.14}\times\frac{1}{0.5\times 10^{-3}}\times 0.01\times 10^{-6}\\ &= 1.59\times 10^{-6}\\ &= 1.6\ \text{MHz}\end{aligned}$$

## CONCLUSION AND FUTURE WORK

An interesting application of the NOLM wavelength conversion scheme is that the same structure can be used as an optical switch when the CW probe signal is replaced by an optical clock signal and in this case the structure is known as a terahertz optical asymmetrical demultiplexer (TOAD) [Ref. 100]. Although NOLM wavelength converters are useful devices, they must be driven by very short return to zero pulses in order to avoid crosstalk problems. They can, however, be efficiently employed for ultrafast wavelength conversion by incorporating additional fiber Bragg grating elements

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**UTRERAS TELLO A. J. – Full Time Professor, Escuela Politécnica Nacional, Ecuador.**

**LICENKO G. L. – Full Time Professor, Vinnitsia National Technical University, Ukraine.**

**REYES CIFUENTES V. H. – Full Time Professor, Escuela Politécnica Nacional, Ecuador.MENA VILLACIS R. I. – Full Time Professor, Escuela Politécnica Nacional, Ecuador.**

**JARAMILLO PINOS E. S. – Full Time Professor, Escuela Politécnica Nacional, Ecuador.**