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Performance Analysis and Comparison between Coarse WDM and Dense WDM

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Abstract - Although optical fiber communication is the best for transmitting data at a high rate, we are trying to push the data rate even higher. While the fiber channel may be capable of transmitting terabit-per-second data rates, no existing single communication system can make complete use of this speed. Adding more and more fibers to the system as a method of increasing speed is uneconomical as we know the global network is made of a large submarine cable networks that is expensive to modify. An alternative solution to this is Wavelength Division Multiplexing (WDM) where each modulated signal is transmitted at an individual frequency, allowing full duplex data transmission. In WDM systems the available fiber bandwidth is divided into separate channels with each channel carrying one signal, thus increasing the overall data rate without increasing the number of fibers. The data rate of each channel can be limited, but with many channels the total data rate is considerably higher. At the receiver end of the link, a de-multiplexer separates the wavelengths and routes them into different fibers, which all terminate at separate receivers. The spacing between the individual wavelengths transmitted through the same fiber serve as the basis for defining Dense WDM and Coarse WDM. For cost-effective solutions to their transport needs, Coarse WDM is becoming more widely accepted as important transport architecture.

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PERFORMANCE ANALYSIS AND COMPARISON BETWEEN COARSE WDM AND DENSE WDM

Strictly as per the compliance and regulations of :

Performance Analysis and Comparison between Coarse WDM and Dense WDM

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Abstract - Although optical fiber communication is the best for transmitting data at a high rate, we are trying to push the data rate even higher. While the fiber channel may be capable of transmitting terabit-per-second data rates, no existing single communication system can make complete use of this speed. Adding more and more fibers to the system as a method of increasing speed is uneconomical as we know the global network is made of a large submarine cable networks that is expensive to modify. An alternative solution to this is Wavelength Division Multiplexing (WDM) where each modulated signal is transmitted at an individual frequency, allowing full duplex data transmission. In WDM systems the available fiber bandwidth is divided into separate channels with each channel carrying one signal, thus increasing the overall data rate without increasing the number of fibers. The data rate of each channel can be limited, but with many channels the total data rate is considerably higher. At the receiver end of the link, a de-multiplexer separates the wavelengths and routes them into different fibers, which all terminate at separate receivers. The spacing between the individual wavelengths transmitted through the same fiber serve as the basis for defining Dense WDM and Coarse WDM. For cost-effective solutions to their transport needs, Coarse WDM is becoming more widely accepted as important transport architecture. The commercial availability of Coarse WDM systems offering these benefits makes the technology a viable alternative to Dense WDM systems for many metro and access applications .Coarse WDM has not always been a popular choice. Coarse WDM systems did not generate significant interest among service providers the invention of Erbium-doped fiber amplifiers (EDFA) with large bandwidth is largely responsible for popularizing this technique. In terms of multi-wavelength signals, so long as the EDFA has enough pump energy available to it, it can amplify as many optical signals as can be multiplexed into its amplification band. These properties of EDFAs have enabled us to use Dense WDM (DWDM) technique, which uses denser channel spacing in order to achieve even higher bit rate. In this paper, performance analysis of Dense WDM technique was explored and different aspects of a system with Dense WDM were discussed. Also, comparisons were made between Coarse WDM and Dense WDM on the basis of these analyses. Dense WDM technique has the advantage of higher bit rates and is well equipped for long haul applications; however, this also imposes higher cost, power consumption and also adds to the complexity of the system. These shortcomings are mostly neglected by the advantages it provides over other multiplexing schemes.

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I. Introduction

In optical communications system the transmitter is a light source whose output acts as the carrier wave. Although frequency division multiplexing (FDM) techniques are used in longer broadcast systems, most optical communication links use time division multiplexing (TDM) techniques.

The components that are used to transmit or receive the optical signal are usually semiconductors devices. For transmission the most common light source used are laser diode (LD) and light emitting diode (LED) where they have different specification according to power spectrum and fabrication. At the receiving end of the optical link a PIN photodiode or Avalanche photodiode (APD), acts as a photo detector and converts the modulated light back into an electrical signal. The photodiode current is directly proportional to optical power.

II. Basic Concept of CWDM and DWDM

a) Dense WDM (DWDM) System

Dense wavelength division multiplexing, or DWDM for short, refers originally to optical signals multiplexed within the 1550 nm band so as to leverage the capabilities (and cost) of erbium doped fiber amplifiers (EDFAs), which are effective for wavelengths between approximately 1525-1565 nm (C band), or 1570-1610 nm (L band). EDFAs were originally developed to replace SONET/SDH optical-electrical-optical (OEO) regenerators, which they have made practically obsolete. EDFAs can amplify any optical signal in their operating range, regardless of the modulated bit rate.

b) Corase WDM System

Coarse WDM (CWDM) in contrast to conventional WDM and DWDM uses increased channel spacing to allow less sophisticated and thus cheaper transceiver designs. To again provide 16 channels on a single fiber CWDM uses the entire frequency band between 2nd and 3rd transmission window (about 1310/1550 nm respectively) including both windows (minimum dispersion window and minimum attenuation window) but also the critical area where OH scattering may occur. Today, CWDM typically uses 20 nm spacing (3000 GHz) of up to 18 channels.

c) Overall concept about DWDM and Coarse DWDM

Optical communications by Dense Wavelength Division Multiplexing (DWDM) uses □100 wavelength channels enabling high-speed, high-capacity optical communication system for the Internet age. DWDM systems are relatively expensive and are cost effective for long haul communication. Medium to short-haul networks, are very cost sensitive, although network traffic is quite large as in the metro cities. A new trend is to use Coarse Wavelength Division Multiplexing2 (CWDM) system in these networks to lower the cost dramatically at sufficient bandwidth capacity. In addition, to the stability required for DWDM sources passive modules such as mux/demux and add/drop modules used in DWDM systems also need to have very narrow filtering or wavelength separating characteristics that stay stable over a considerable temperature range. These filters are required to have very stringent tolerance and are difficult to fabricate, thus making these components inherently expensive. For a CWDM system, on the other hand the spacing between channel wavelengths is large so that the requirements and tolerances for components and modules are more relaxed. Less-stringent tolerances result directly in substantial cost reduction of a CWDM system as compared that of with a DWDM system. This price differential makes it very attractive for CWDM systems to be used in the Metro Area Network (MAN) applications where the cost is most sensitive to subscribers.

III. Fundamental Of Optical Fiber

The early all-glass fibers experienced large amount of optical losses thus limiting the transmission distance. This was because the transparent transmitting rod (typically composed of silica glass with a refractive index of 1.5) was surrounded by air and as a consequence, excessive losses occurred at any discontinuities of the glass-air interface. This realization motivated scientists to develop glass fibers that included a separate glass coating. The fiber was made of two layers. The innermost region of the fiber referred to as the core, was used to transmit the light while the glass coating or the cladding prevented the light from leaking out of the core by reflecting it within its boundaries.

a) System Crosstalk

Crosstalk occurs in multi channel optical transmission systems. There are two types of crosstalk noise discussed and analyzed in this work. First is the inter band crosstalk and it's a known also by "out of band" crosstalk. Second is intraband it's known by "inband". Crosstalk can be caused by the following: 1) The spectral skirts of one channel entering the de-multiplexing and filtering pass-band of another cause crosstalk.2) Practical limits on selectivity and isolation cause crosstalk. Non-linear effects within the fiber at the high power densities possible in single mode systems can cause crosstalk or cross modulation. 3) The mechanism is Raman scattering, which is a non-linear stimulated scattering effect that allows the optical power at one wavelength to affect scattering and thus the optical power in another wavelength.

b) System Power Penalty

In optical communication the receiver sensitivity is defined with respect to the receiver noise for several basic detection scenarios. The highest sensitivity means the lowest value of the received optical power that is needed. The sensitivity of the photo-detector of real receiver is degraded due to the impact of two principal noise contributions, the thermal noise (in PIN photodoides) and quantum shot noise (in APD). The engineering consideration is to include the impact of other impairments that degrade the receiver sensitivity. Some of these impairments, such as a finite extinction ratio and chromatic dispersion, are very important and should be considered in most practical situations, while the others, such as fiber modal noise and timing jitter, might play an important role only in some specific cases. Power Penalty due to Intensity Noise, Power Penalty due Timing jitter, and Power Penalty due Signal Crosstalk.

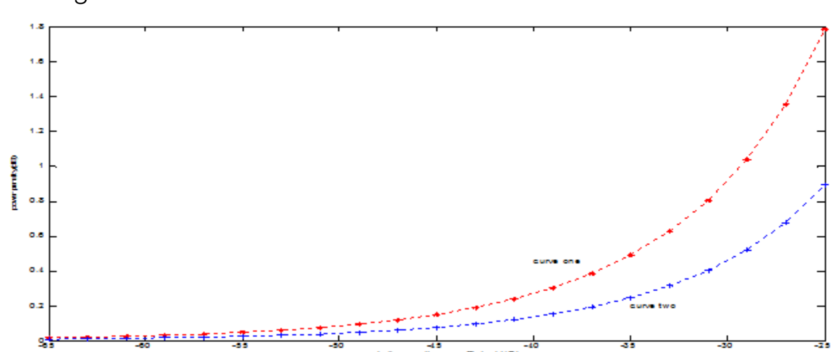

Figure 1 : Relation between power penalty and crosstalk coupling coefficient

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IV. Simulations of Conventional WDM

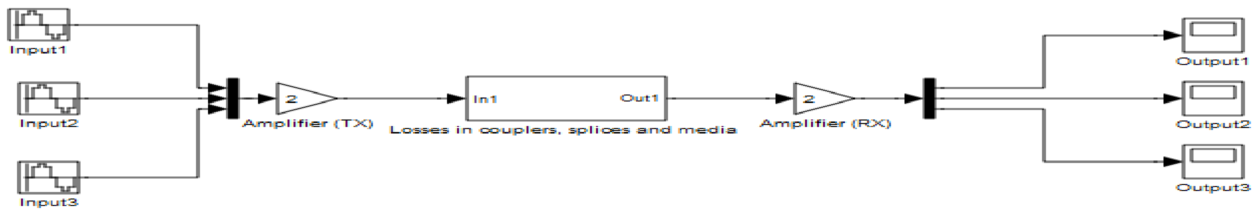

Figure 2 : Basic model for wavelength division multiplexing

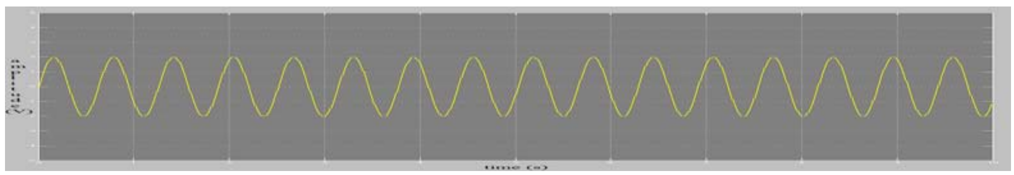

Figure 3 : Input standard sinusoidal signal

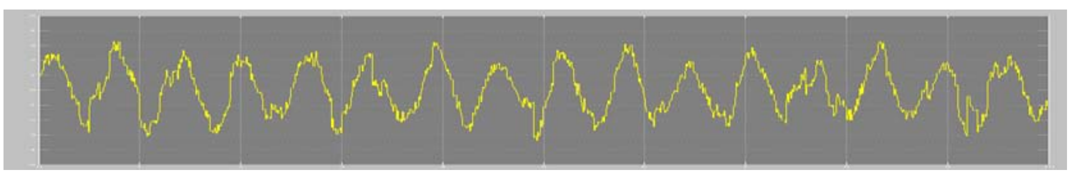

Figure 4 : Distorted output with noise

V. Simulations for Dwdm

This simulation simulates a realistic scenario of a 40Gbps DWDM link with inter-channel spacing of 50 GHz. Forty individual channels carrying PRBS data are transmitted over a 50 km length of ITU-T G.652 single mode dispersive fiber. The design objective is to utilize distributed Raman amplification to compensate for the link attenuation thereby effectively increasing the inter-EDFA span in a longer haul link.

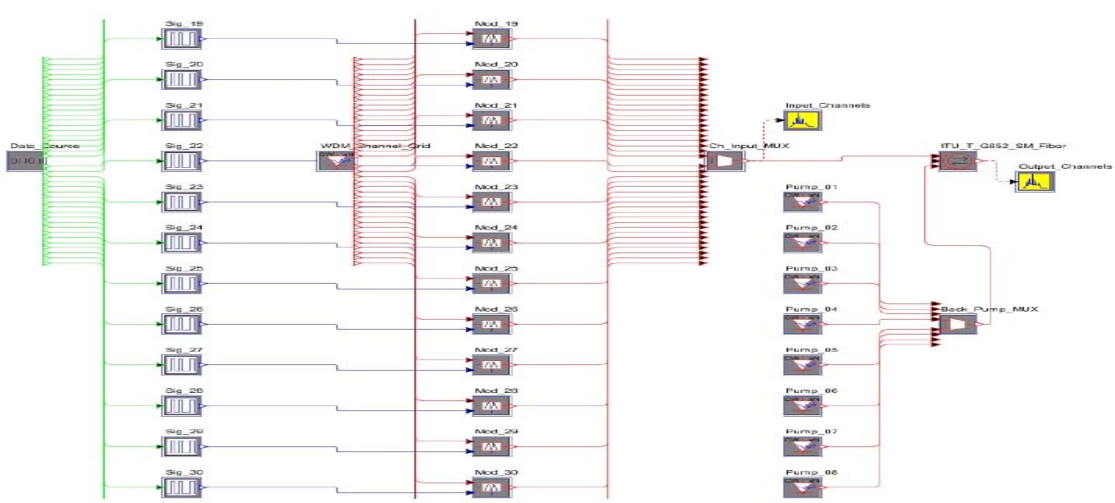

Figure 5 : Basic Diagram for DWDM

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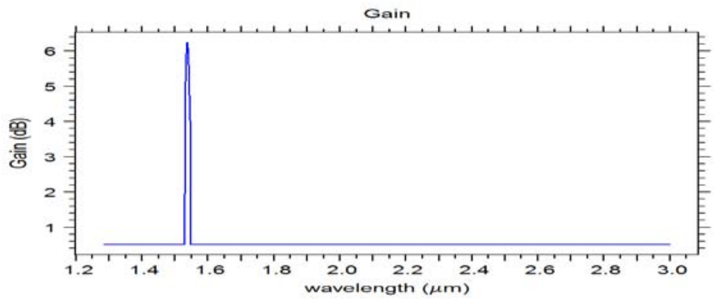

Figure 6 : Frequency response of the DWDM link

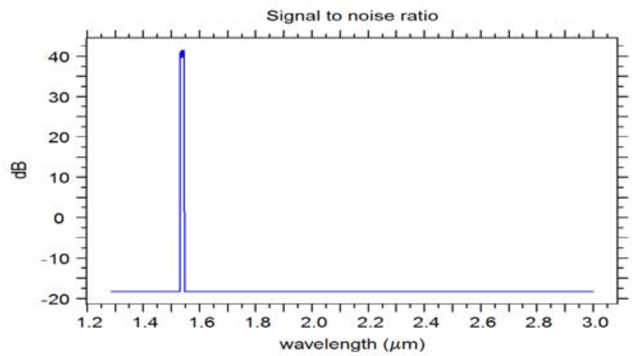

Figure 7 : SNR of the DWDM link

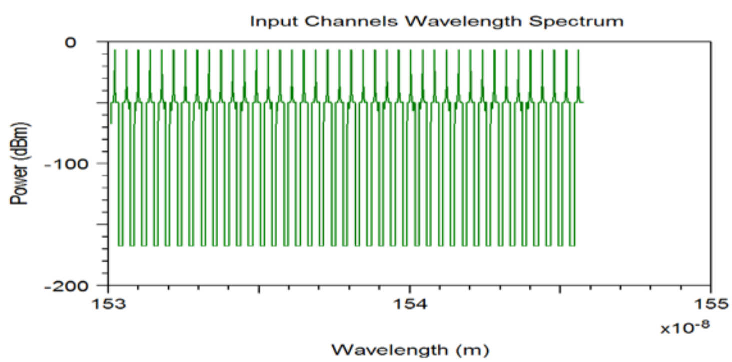

Figure 8 : Input channel wavelength spectrum of the DWDM link

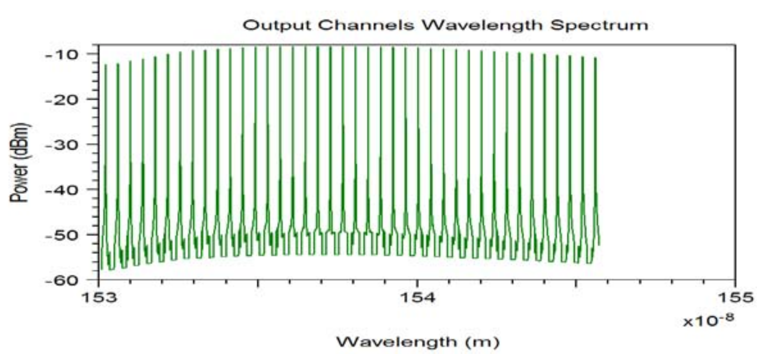

Figure 9 : Output channel wavelength spectrum of the DWDM link

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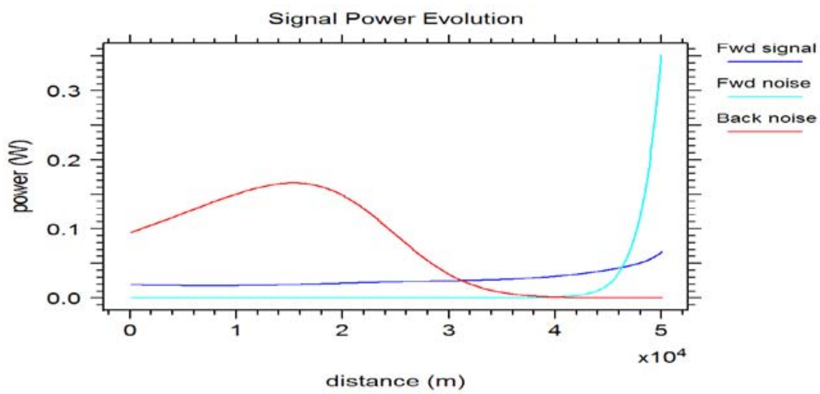

Figure 10 : Signal power and noise power over the distance of the fiber in the 40 DWDM link

VI. Simulations for Cwdm: This is One of the Cwdm Structure

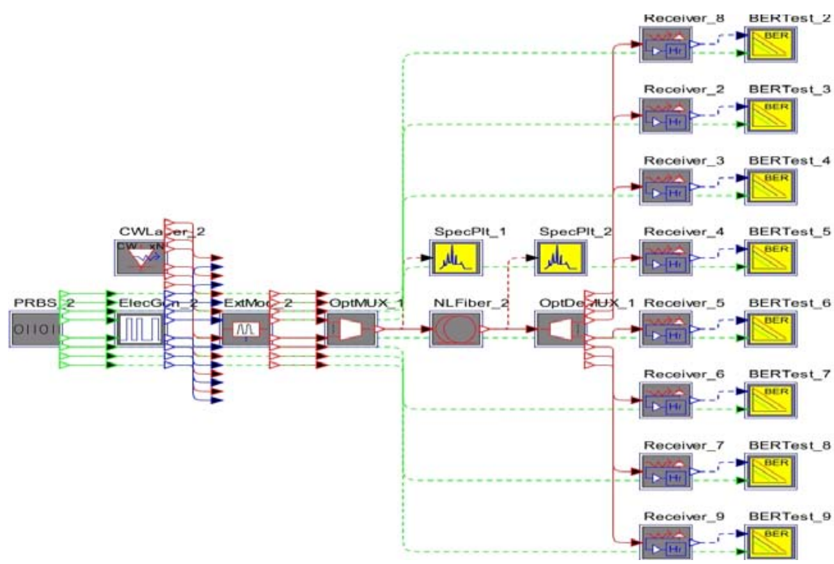

Figure 11 : Simple Diagram of CWDM

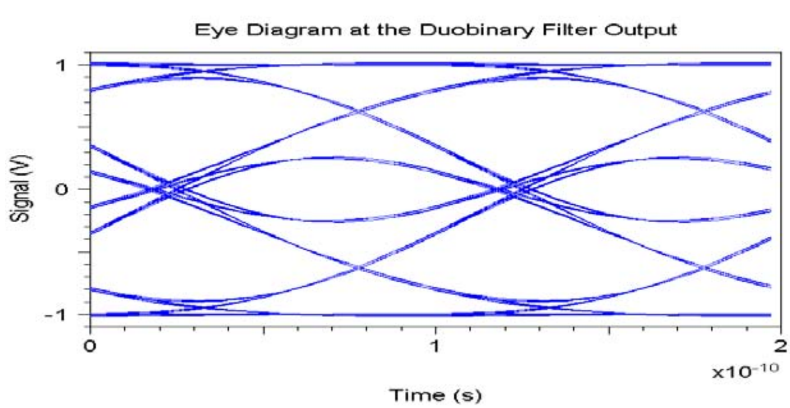

Figure 12 : Eye Diagram

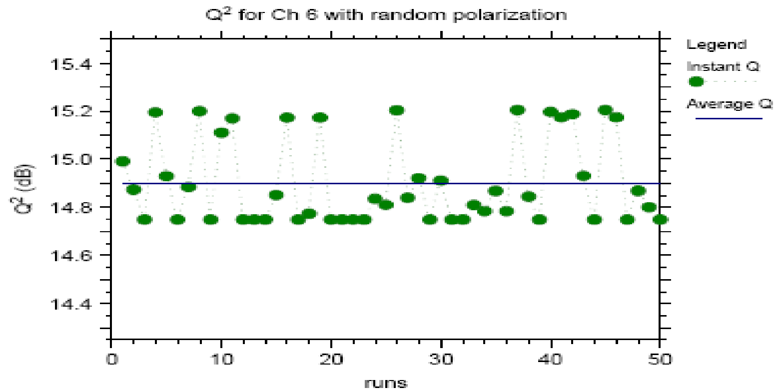

Figure 13 : Polarization with adjacent channel

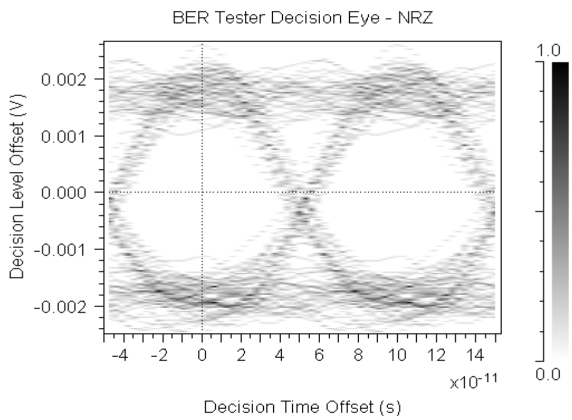

Figure 14 : NRZ Operatiom in CWDM

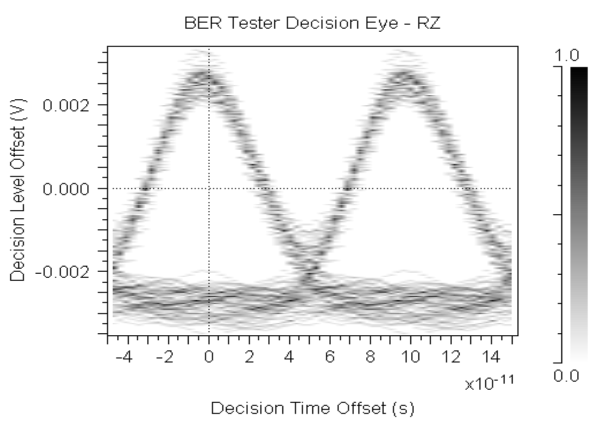

Figure 15 : RZ Operation in CWDM

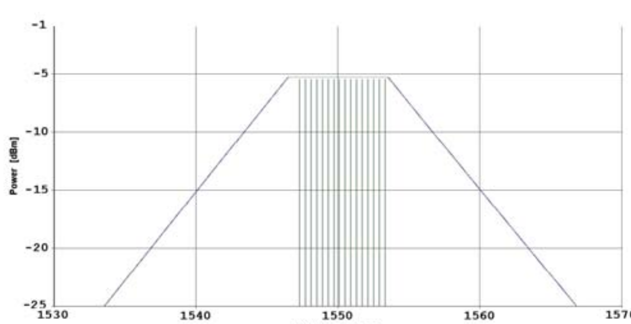

Figure 16 : Response with multi wavelength in operation

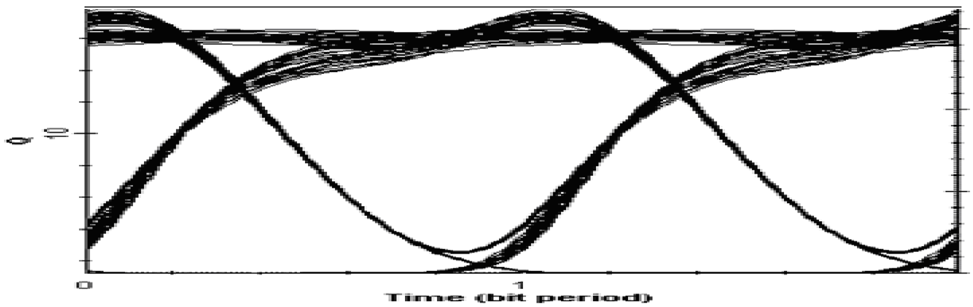

Figure 17 : Simple dispersion of CWDM

VII. Advantages of CWDM

a) CWDM systems can make high optical fiber transmission capacity; can improve the utilization of the resources of optical fiber.
b) Another advantage of CWDM is small volume.
c) Lower cost for more capacity in the short-haul
d) Compare with the conventional WDM, CWDM has better rate and agreement transparence
e) CWDM has the very good flexibility and expansibility
f) For long haul applications, optical amplification is well
g) The use of CWDM system can improve business quality and very low polarization sensitivity.
h) Less optical losses and high Mechanical sensitivity.
i) Easily used in metro network
j) Excellent performance.

VIII. Advantages of Dwdm

a) The things of note are:
b) Narrow channel spacing or wavelength selection, giving rise to denser channels in the same wavelength range.
c) Reduced Raman crosstalk without required mitigation techniques.
d) Cost effective way of increasing system capacity without introducing more fibers to the system.
e) With selective wavelength spacing, four-wave mixing is possible.
f) Higher number of wavelengths (up to 8) supported.
g) Higher distance capability with Erbium Doped Fiber Amplifier (EDFA). Maximum link distance of ~30 km.
h) Repeater or amplification sites are reduced, resulting in a large savings of funding.
i) Maximum number of channels is up to ~40 as of today (theoretically hundreds of channels are possible).
j) For long haul applications, optical amplification is well proven.
k) Very useful as upgrades to already installed systems.

IX. Some Features of CWDM and DWDM

Features	CWDM	DWDM
Wavelength per fiber	8-16	40-80
Wavelength spacing	2500GHz	100GHz
Wavelength capacity	Upto 2.5 Gbps	Upto 10Gbps
Aggregate fiber capacity	20-40Gbps	100-1000Gbps
Applications	Metro access	Metro access, regional access

Features	CWDM	DWDM
Raman crosstalk	Significant	Reduced
Four wave mixing	Not applicable	Selective wavelength spacing
Maximum link distance	11-15km	20-30km
Wavelength selection	Standard ITU wavelengths	Uneven

X. Conclusion

CWDM transmitter cards have lower power consumption than DWDM transmitter cards, since there is no need for temperature control of the laser diodes. However, the uniformity of the fiber attenuation over the DWDM wavelengths is better than the CWDM, so for medium and long haul applications DWDM will be the best solution even for low channel counts. In CWDM, there are usually eight different IR channels, but there can be up to 18, whereas in DWDM, there can be dozens. Because each IR channel carries its own set of multiplexed RF signals, it is theoretically possible to transmit combined data on a single fiber at a total effective speed of several hundred Gb/s. The use of DWDM can multiply the effective Bandwidth of a fiber optic communications system by a large factor. But its cost must be weighed against the alternative of using multiple fibers bundled into a cable. DWDM uses temperature-stabilized lasers in order to fix the center wavelength and narrow band filters, giving many densely spaced channels. Typical channel spacing is 100GHz, corresponding to a channel spacing of approximately 0.8nm. The wavelengths used are specified by ITU and the technology is well proven. By packing WDM channels denser than in CWDM systems, 100 GHz spacing (approx. 0.8 nm), more channels and higher capacity can be achieved using DWDM. ITU-T recommendation G.694.1 defines the DWDM channel spectrum. Using Trans Packet's DWDM MUX/DMUX units, upgrade to 40 wavelength channels is viable. However, the main advantage of CWDM is the cost of the optics which is typically one third of the cost of the equivalent DWDM optic. This difference in economic scale, the limited budget that many customers face, and typical initial requirements not to exceed 8 wavelengths, means that CWDM is a more popular entry point for many customers. A customer can start with 8 CWDM wavelengths but then grow by introducing DWDM wavelengths into the mix, utilizing the existing fiber and maximizing return on investment. CWDM system was highly valued by the industry due to the above advantages. In the while, it is be widely used of Telecommunications, broadcasting and TV, enterprise nets, campus network and other field. But there is also some disadvantages, such as less light channel, function of equipment are not perfect and so on. With the development of technology and the expansion of the market, CWDM technology can have a good application prospect. Now a day, CWDM and DWDM network equipment is used in optical transport requirements for the following advantages:

- Low-cost initial set up.
- Less maintenance cost
- Provide secure operation
- Network can be upgraded easily
- Easy conversion capabilities up to 44+wavelengths
- Easy upgrade to support 100Gbps services
- Non traffic effective network upgrades
- Provides reliable and standards operation
- Provide operational security

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