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What is DWDM?

White Paper WP01-DWDM (1)

This paper describes some of the basic principles of DWDM

Introduction

To understand what DWDM is and how it works, there are a few other underlying concepts that must be understood. This paper first attempts to describe some of them, such as Time Division Multiplexing (TDM), frequency as applied to fiber optics, and optical data transmission at a very basic level.

This paper then proceeds with a description of Dense Wavelength Division Multiplexing (DWDM). It is by no means an exhaustive definition; such a definition would require several voluminous textbooks.

DWDM itself can be defined as follows: DWDM is a multiplexing technique used to increase the bandwidth of a single mode optical fiber, enabling simultaneous transport of several different signals on one fiber.

The all-optical multiplexing technique used in DWDM is format as well as protocol independent, enabling transport of different signal formats on different wavelengths at the same time. Simply put, you can send a SONET data stream on one wavelength and an Ethernet data stream on another wavelength at the same time, and they will not interfere with each other.

Time Division Multiplexing

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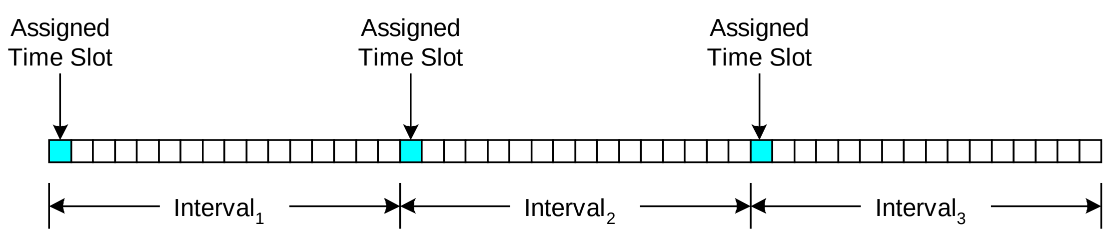
Time Division Multiplexing in general is a fairly simple concept, something most school children do every day. On the first day of school, each child is assigned a seat in a classroom. It is "their" seat for a certain period of time. During the next class it becomes another child's seat and so on for the entire school day. The next day this sequence of events is repeated again for the entire school year.

Time Division Multiplexing as used in communications is essentially the same: A particular data stream is assigned a time slot with other data streams. The assigned time slots repeat over a given interval. As used here, each data stream is a child and the assigned time slot is "their" seat in the classroom. The interval used here is once a day, however in fiber optic communication the interval is usually in the millisecond range. SONET data streams rely heavily on TDM.



As illustrated above, the assigned time slot repeats once every interval. This technique allows a constant data stream to be delivered through the fiber.

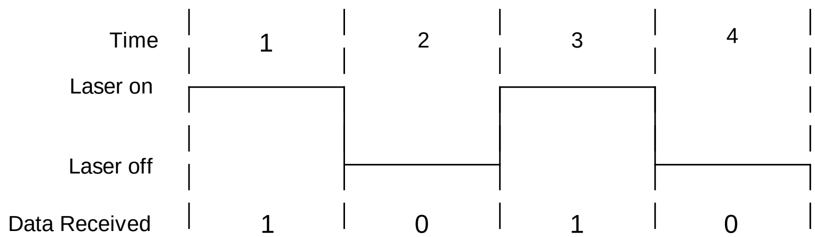
DWDM Frequencies

The International Telecommunication Union (ITU), based in Switzerland, has defined specific frequencies for wave division multiplexing in recommendation ITU-T G.692. This allows equipment from multiple vendors to interoperate at different wavelengths without interference. The ITU defined frequencies rather than wavelengths for a very good reason; the wavelength of a signal can change depending on the medium it is traveling through. An explanation of the phenomenon is beyond the scope of this paper.

Frequency as used in this paper generally refers to the frequency of the light coupled into an optical fiber. DWDM frequencies are in the Terahertz (THz) range. One Hertz is one cycle per second, and one terahertz is equal to 10^{12} cycles per second. The ITU reference frequency is 193.1 THz, corresponding to a wavelength is optical fiber of 155.52nm.

Optical Data Transmission

Optical data transmission is quite simple in principal; the light is either on or off. Light on is received as a 1, and off is received as a 0. The data (1s and 0s) are transmitted at a specified rate so the receiver can recover the data, as illustrated below.

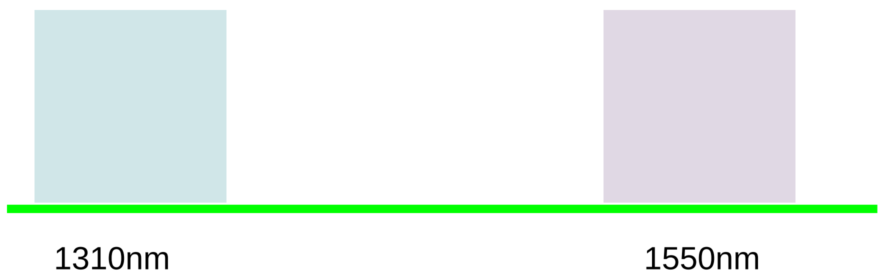


At time = 1, the laser is on, so the data is a one (1). At time = 2, the laser is off, so the received data is a zero (0).

DWDM

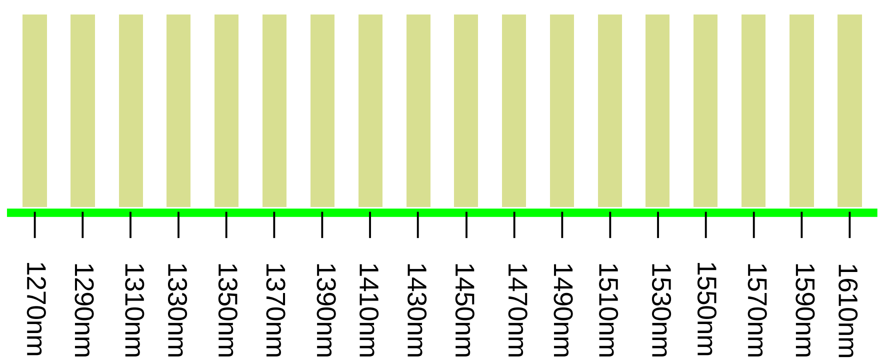
The type of material used to make optical fiber causes the light to be attenuated and different rates, depending on the frequency of the light. There are frequency ranges, or “windows”, in the fiber where there is less attenuation and dispersion than in other areas. (There is a window at 850nm, generally used in multi-mode fiber for short reach applications.)

The precursor of DWDM, WDM, used two windows at 1310nm and at 1550nm as shown below.



The frequency of the light in WDM did not have to be very tightly controlled, as long as it was centered at 1310nm or 1550nm. This allowed twice as much data to be transmitted in a single fiber.

The next step was Course Wavelength Division Multiplexing (CWDM). In recommendation G.694.2, the ITU defines a CWDM grid of 18 wavelengths from 1271nm to 1611 nm. Note that CWDM is defined in wavelengths as opposed to DWDM, which is defined as frequencies. The CWDM grid is shown below:



Note that for technical reasons the ITU defined the wavelengths 1nm higher than the commonly referred to wavelengths. In practice this deviation is meaningless. Compare the DWDM spacing of +-20nm to the channel spacing in a 40-channel DWDM system of approximately 1.6 nm, and the obvious conclusion is that non-DWDM lasers cannot be used for DWDM applications.

In DWDM systems a narrow spectrum and excellent wavelength stability is of crucial importance, because only a small drift in center-wavelength of one of the DWDM lasers may distort the signal of the adjacent channel. The allowed wavelength drift of the laser is specified in ITU-T G.692.

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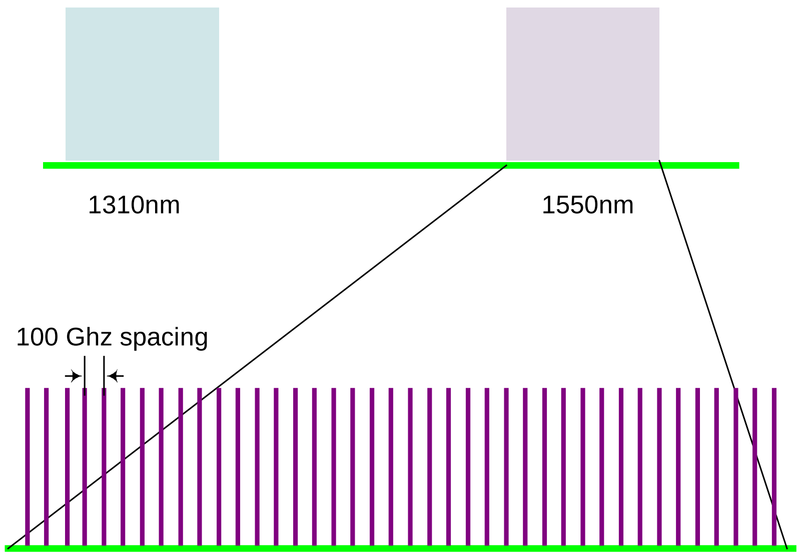

The picture above shows 40 DWDM channels with 100Ghz spacing. 50 Ghz are even 25 Ghz systems are available today. There are also other frequencies defined by the ITU. A complete definition of the available DWDM components is beyond the scope of this paper.

Optical multiplexing and de-multiplexing

DWDM optical transmitters are set to a specific frequency and coupled (multiplexed) together onto a fiber. In order to receive these signals, they have to be split apart (de-multiplexed). This is because optical receivers cannot distinguish one frequency from another.

The device used to accomplished this an Optical Add/Drop Multiplexer (OADM).

Summary

This paper defined the basics of DWDM and its precursor, WDM. It also described some of the concepts behind optical data transmission.

Why WDM?

So, why use WDM at all? Why not simply transmit the data faster? Here is where the Time-Division Multiplexing knowledge comes in. In order to transmit more data through the fiber, the time the data can occupy its assigned "seat" becomes smaller and smaller. As the time decreases, the speed the data is transmitted and received at increases, and so does the cost of the transmitting equipment and the amount of power required. Remember, to match the data throughput of DWDM, the speed would have to be increased by a factor of 40 or more!

It also means that every time the speed is increased, the existing equipment has to be replaced, a very expensive and disruptive event. WDM allows new wavelengths to be added as more bandwidth is needed, resulting in less system disruption.

For information on products that can be used in DWDM networks, please contact Avvio Networks by telephone at (978) 453-5200 or by email at sales@avvionetworks.com.