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SmartOptics | WDM

Coarse and Dense Wavelength Division Multiplexing

There are two main types of technology for wavelength division multiplexing (WDM): coarse (CWDM) and dense (DWDM). They both use multiple wavelengths of light on a single fiber, but differ in their spacing of the wavelengths, number of channels and ability to amplify the multiplexed signals.

Unlike with CWDM, the wavelengths in DWDM are more tightly packed, and connections can be amplified. This means that data can be transmitted much longer distances. CWDM has traditionally been a lower-cost solution, but today the prices for both are comparable. Deciding which solution is best depends on user and network requirements.

WDM Defined

Wavelength Division Multiplexing (WDM) allows different data streams to be sent simultaneously over a single optical fiber network. In other articles, we've used the analogy of an expressway to outline how WDM works to create a single virtual fiber network. Using it to combine multiple services on one dark fiber can maximize the fiber and help organizations meet growing demands without laying or leasing more fiber until it's necessary. There are two main types of WDM technologies used today: Coarse Wavelength Division Multiplexing (CWDM) and Dense Wavelength Division Multiplexing (DWDM).

CWDM allows up to 18 channels to be transported over a single dark fiber, while DWDM supports up to 88 channels. Both technologies are independent of protocol, meaning that any mix of data, storage, voice or video can be used on the different wavelength channels. In fiber terms, the main difference between CWDM and DWDM technologies lies in how the transmission channels are spaced along the electromagnetic spectrum.

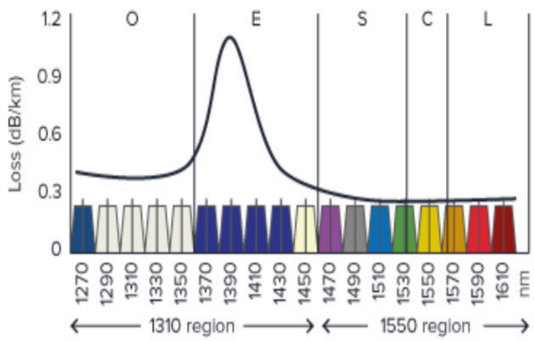
WDM technology uses infrared light, which lies beyond the spectrum of visible light. It can use wavelengths between 1260nm and 1670nm. Most fibers are optimized for the two regions 1310nm and 1550nm, which allow for effective "windows" for optical networking.

Coarse Wavelength Division Multiplexing

CWDM is a technology that allows up to 18 channels to be connected over a dark fiber pair. Two wavelength regions are most commonly associated with CWDM, 1310nm and 1550nm. The 1550nm region is more popular because it has a lower loss in the fiber (meaning the signal can travel farther).

If we use our road analogy, it's like painting 18 lanes on the road, with nine in the 1310 region of the fiber (1270nm to 1450nm) and nine in the 1550 region (1470nm to 1610nm). To achieve this, the wavelengths of each channel are 20nm apart.

CWDM is a convenient and low-cost solution for distances up to 70km. But between 40km and its maximum distance of 70km CWDM tends to be limited to 8 channels due to a phenomenon called the water peak of the fiber (more about this further down). CWDM signals cannot be amplified, making the 70km estimate an absolute maximum.



Dense Wavelength Division Multiplexing

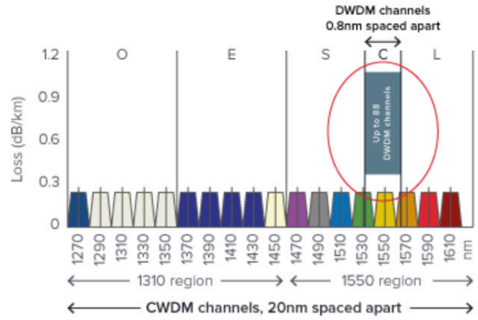
With DWDM, we can convert our road to an 88-lane expressway. DWDM can handle higher speed protocols, up to 100Gbps per channel. Each channel is only 0.8nm apart instead of the 20nm you would find in a CWDM system.

Dense wavelength division multiplexing works on the same principle as CWDM, but in addition to the increased channel capacity, it can also be amplified to support much longer distances.

CWDM and DWDM wavelength comparison

The following figure shows how the DWDM channels fit into the wavelength spectrum compared to CWDM channels. Each CWDM channel is spaced 20nm apart from the adjacent channel. In the figure, we use colors to differentiate the 8 CWDM channels in the 1550 region. For the 1310 regions, no color schemes have been standardized.

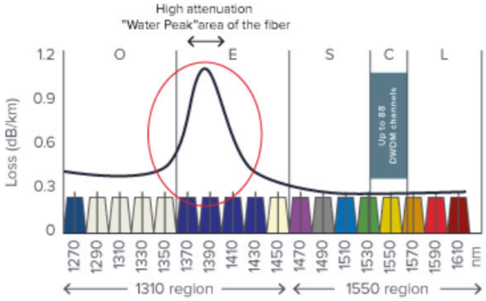
For DWDM on the other hand, all the DWDM channels are within the 1530 and 1550nm CWDM regions. For DWDM channels, a color scheme has not been standardized either: probably just as well because remembering and differentiating 88 different colors for the DWDM channels with the naked eye might also be a strain. Instead, we use a block to indicate where they are grouped.



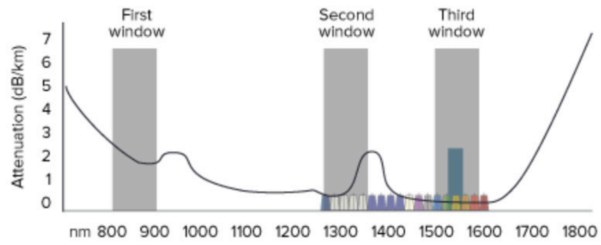
Why not just add more wavelengths?

CWDM and DWDM increase the amount of traffic that can be connected through a dark fiber. So why not add more? Why stop at 18 CWDM channels and 88 DWDM channels? The reason it's not possible to add more is that fiber itself isn't linear.

For longer distances, over 40 km, CWDM is restricted to 9 working channels due to a chemical property in the fiber called the water peak. The water peak is an area of high loss in the 1300nm region of the fiber that affects CWDM channels 1370nm to 1430nm. In this region, the signal loss is 1.0dB/km as opposed to 0.25dB/km in the 1550 region. This doesn't mean that CWDM channels in the 1310nm region cannot be used, just that the distance is decreased.

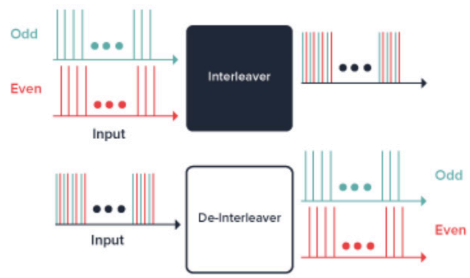


DWDM channels are in the 1550nm region of the fiber, which is the area in the fiber that has the lowest loss. The 1550 region is in a stable, low-loss valley surrounded by areas of high loss on either side. On either side of the 1550 region, the loss of the fiber quickly increases and becomes unusable for optical networking applications.



50GHz DWDM wavelength spacing using an interleaver

A convenient way to increase the number of DWDM channels from, say, 40 to 80 is to use an interleaver. An interleaver multiplexes 50GHz-spaced DWDM signals onto a 100GHz-spaced channel plan. The 50 and 100GHz signals are commonly referred to as odd and even signals, and it is these signals that are combined or interleaved together typically to move from 40 to 80 channels in the C-band of the fiber.



Should you use CWDM or DWDM?

As discussed earlier, CWDM connectivity is limited to 70km, while DWDM can transmit up to 80km. But perhaps even more importantly, DWDM can be amplified for longer distances. Since all DWDM channels tend to predominantly sit in the “flattened-out” 1550nm range of the fiber, they lend themselves better to being amplified.

	DWDM	CWDM
Distance	70km unamplified	80km unamplified
	1000km+ amplified	Not applicable
Channels	88 (Using interleaver)	18 (Distances limited in the water peak)
Spacing	0.8nm	20nm
Protocols	All including 100G and beyond: 1/10/40/100GE and 8/16/32GFC	Up to 10GE and 8GFC (40G using 4x10G CWDM)

If a CWDM solution is already in place and the system still holds capacity for further growth, then CWDM should be considered. If the capacity is getting full, then there are two options: to start again with a DWDM system with a higher capacity or to overlay a “hybrid DWDM” network over the top of channels 1530 and 1550nm, which creates an additional 26 new channels over the existing CWDM network.

DWDM systems have traditionally been designed and used by telcos for fixed, vertically integrated systems, and as such have brought large real estate requirements. This is why CWDM was long the more popular choice for corporate data center connectivity. But today there are more flexible solutions for DWDM also at the corporate data center level, making it a much more realistic option.

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