White Paper

Understanding DWDM & Optical Communication

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Without optical communication we would be still sending mail, going to the newsstand to buy a newspaper, sending mail and postcards and renting movies, no internet would have been possible, no digital communications as we know it.

Among the many unsung technologies that make all this possible, Dense Wavelength Division Multiplexing (DWDM) is without any doubt one of the most important. In a nutshell, DWDM has the capability to send multiple signals on the same fiber, using different wavelengths. One of the nice characteristics of the optical fiber is that different channel can travel one close to the other with very little, almost negligible in most cases, crosstalk. Thanks to DWDM, we're now able to pack 10 TBits/s of traffic per single fiber and send it more than 1000Km. How much is that? It is about 2,000,000 simultaneous Netflix HD streams in a wire smaller than a human hair!

DWDM started as high end transport technology, but made its way to regional and metropolitan network and finally into transceivers. Several generation of DWDM transceivers have already been released (XENPAK, X2, XFP, SFP+), providing networking equipment not only with the capability to transport a huge amount of data with a single fiber, simplifying cabling and reducing cost, but also reducing the number of equipment needed. Before, if an operator wanted to connect 2 switches located some tens of kilometres apart, it needed non-coloured optics on the switch, connected with the same kind of optics on the transport system transponder shelf, this last piece of equipment did the conversion from non-DWDM wavelengths to DWDM wavelengths before they were optically multiplexed and transported over the DWDM link, the opposite process at receiving site. With DWDM transceivers directly on the switch, they can be connected directly to the optical multiplexing gear. It is evident that this solution has numerous advantages.

Advantages

- Reduction of the number of equipment used
- Cost reduced, since two "grey" transceivers and one transponder per wavelength will be replaced by a single DWDM transceiver
- Power reduced consumption and consequently cooling needs
- Foorprint reduced (particularly important for co-located data centers)
- Reduced latency, since an optical-electrical-optical conversion stage has been removed

If it is clear that DWMD optics come with great advantages, but the device is more complex and more optical variables comes into play. With uncoloured optics everything is pretty simple , they come with a "distance" tag attached (10Km, 40Km, 300m), power budget is pretty much the only parameter that the end user should care about. With DWDM there is no specific target distance power levels are of course still important, but other parameter, such as OSNR (optical signal to noise ratio) and CD (chromatic dispersion) come into play, in fact, often specifications are given in the form of a combination of the three mentioned parameters.

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An optical signal travelling on a fiber experiences an attenuation of about 0.2dB/Km, so if you want to transmit it for long distances it needs to be amplified along the way and probably more than once. Erbium doped fiber amplifiers (EDFAs) do exactly this, but, at every amplifying stage, noise is added to the signal. The longer you want to go, the more amplifiers you need, the noisier the signal at the end of the line. Below a certain OSNR, which depends on the device to device, becomes impossible to detect the signal with an acceptable bit error rate.

Even if the lasers used for optical transmission have a narrow bandwidth, they are not purely monochromatic and since the refractive index of a fiber depends on the wavelength, different components will reach the receiver in different times, spreading the pulse.

Pulse broadening due to chromatic dispersion

Now, In order to better understand why OSNR and CD matter, let's have a look at the effect they have on the optical eye.

Fig 1. Originally, at transmitter, it is clear what a "1" or "0" are. A simple threshold in the middle of the eye will discriminate reliably between "1" and "0".

Fig 2. Add Chromatic dispersion, negative (~ - 400ps/nm).

Fig 3. Or positive (~1300ps/nm) and as you can see the eye opening is reduced in both amplitude (vertically) and time (horizontally). For a receiver, it gets more difficult to decide if the detected signal is a "1" or a "0".

Fig 4. Now add OSNR on top of chromatic dispersion and you can see that at this point it becomes really problematic to guarantee error free transmission.

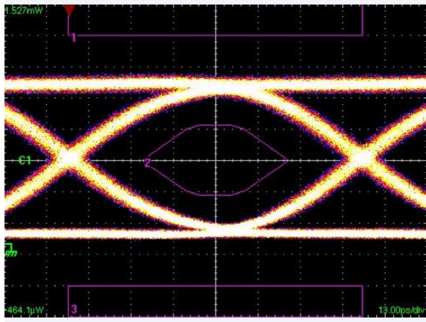

Fig 1.

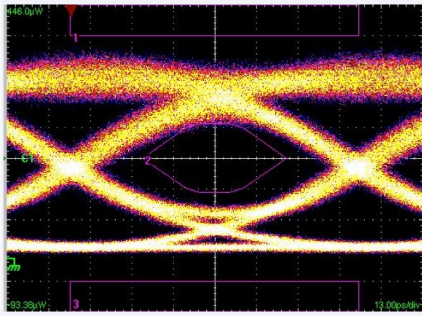

Fig 2.

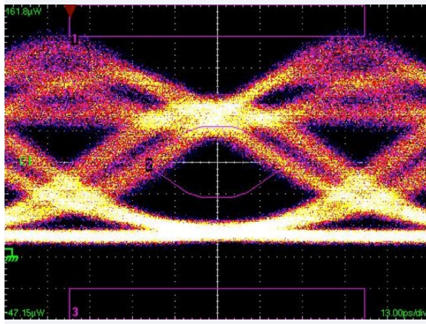

Fig 3.

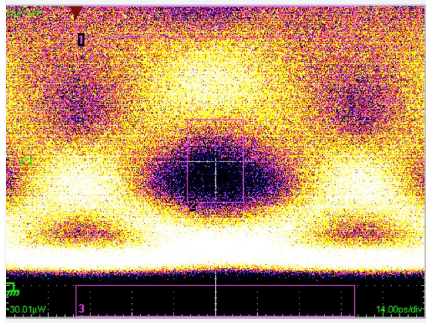

Fig 4.

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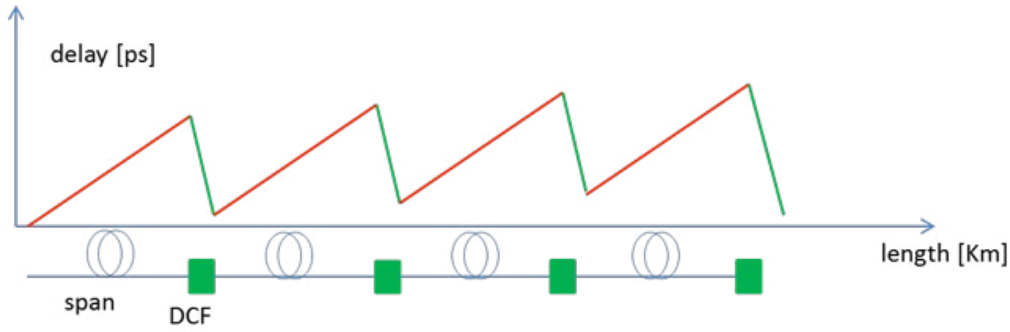
For chromatic dispersion there are counter measures: the simplest is inserting in the network spools of fiber with dispersion opposed to the one accumulated during transmission so that slow components will reach the faster one and the pulse duration will squeeze again.



Link dispersion with DCF units

Of course this comes with a cost; dispersion compensating units are another piece of equipment that needs to be purchased and they attenuate the signal.

Against OSNR there is not much to do, the signal needs to be converted back in the electrical domain and retransmitted.

So, "DWDM" does not mean only "precise wavelength", that is just one piece of the puzzle, it means performance. The cost of poor performance can be very high; if the target BER can't be delivered at the other side of the optical line, there is no other choice than to add an intermediate regeneration site, which is very expensive.

There is only one way to DWDM: robust design, comprehensive validation and careful production test.

ProLabs can offer all this, thanks to its experience and wide portfolio. We can offer DWDM solutions in multiple form factors and bit rate, tested to deliver carrier class quality.

Visit **www.prolabs.com** for more white papers and downloadable data sheets.

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