

From O to L: The Future of Optical-Wavelength Bands

Intercity and metro ring fiber already carry signals on multiple wavelengths to increase bandwidth. Fibers entering the home will soon do the same. Vendors are preparing for it.

By Laurent Gasca ■ *Draka*

Installing new optical fiber requires a huge investment whose return is not fully realized for several years. During that time, technological evolution can change projections of financial return. This article explains how optical telecom systems are evolving with regard to band expansions, and alerts readers to some of the pitfalls.

Contrary to popular belief, further decreases in the OH absorption peak (also called the “water peak,” because the OH bonds due to included water in older fiber absorb certain wavelengths of light) will lead to a *reduction* in the transmission window, not an increase. We also discuss trends toward use of the C- and L- bands, as well as loss requirements for present and future fiber generations.

THE EVOLUTION OF TRANSMISSION BANDS

Several transmission bands have been defined and standardized, from the original O-band to the U/XL-bands (see Table 1). The E- and U/XL-bands have typically been avoided because they correspond to high transmission loss re-

gions. The E-band represents the water peak region, while the U/XL-band resides at the very end of the transmission window for silica glass.

Several types of optical telecom systems have been developed, some based on time-division multiplexing (TDM) and others on wavelength-division multiplexing (WDM), either dense WDM (DWDM) or coarse WDM (CWDM). First, let’s review the high-performance systems, because a good understanding of these systems is helpful in understanding the industry trend toward systems capable of even higher performance.

DENSE WAVELENGTH-DIVISION MULTIPLEXING

DWDM systems were developed to cope with the rising bandwidth needs of backbone optical networks. The narrow spacing (down to 25 GHz or 0.2 nm)

between wavelength bands increases the number of wavelengths and enables data rates of several terabits per second (Tbps) in a single fiber.

These systems were first developed for laser-light wavelengths in the C-band, and later in the L-band, leveraging the wavelengths with the lowest attenuation rates in glass fiber as well as the possibility of optical amplification. Erbium-doped fiber amplifiers (EDFAs, which work at these wavelengths) are a key enabling technology for these systems.

The relationship between WDM and optical amplification spurred billions of dollars in research and development throughout the 1990s for applying optical amplification in other telecom bands, using Raman amplification and thulium-doped fiber amplifiers. In order to meet the demand for “unlimited bandwidth,” it was believed that

Both EPON and GPON are time-division multiplexing systems.

Name	O	E	S	C	L	U/XL
Wavelength range (nm)	1260 - 1360	1360 - 1460	1460 - 1530	1530 - 1565	1565 - 1625	1625 - 1675
Note	Original band	Water peak band		Bands used by the higher performance systems		Not used



Table 1. ITU-T definition of telecom optical wavelength bands. (The arrow stands for the wavelength increase and the general trend toward higher performance systems.)

DWDM would have to be extended to more bands. Progress toward this end was stalled by two events:

1. The bursting of the telecom industry “bubble” in 2000; and
2. The emergence of very high bit-rate technologies – 2.5-, 10- and 40-Gbps data rates in commercial products with the outlook for more than 100 Gbps, according to research papers.¹

The only real success for WDM was with the C-band and EDFAs. Despite great expectations, the number of installed systems using all-Raman solutions worldwide can be counted on one hand.

In the future, however, the L-band will also prove to be useful. Because EDFAs are less efficient in the L-band, the use of Raman amplification technology will be re-addressed, with related pumping wavelengths close to 1485 nm.

COARSE WAVE-DIVISION MULTIPLEXING

CWDM is the low-cost version of WDM. Generally these systems are not amplified and therefore have limited range. They typically use less expensive light sources that are not temperature-stabilized. Larger gaps between wavelengths are necessary, usually 20nm. Of course, this reduces the number of wavelengths that can be used and thus also reduces the total available bandwidth.

Current systems use the S-, C- and L-bands because these bands inhabit the natural region for low optical losses in glass fiber. For example, Alcatel-Lucent’s eight-wavelength CWDM system extends across the 1470-to-1610 nm range.² Although extension into the O- and E-band (1310 nm to 1450 nm) is possible, system reach (the distance the light can travel in fiber and still provide good signal without amplification) will suffer as a result of losses incurred by use of the 1310 nm region in modern fibers.

TIME-DIVISION MULTIPLEXING

TDM systems use either one wavelength band or two (with one wavelength band allocated to each direction). TDM solutions are currently in the spotlight with the deployment of fiber-to-the-home (FTTH) technologies. Both EPON and GPON are TDM systems. The standard bandwidth allocation for GPON requires

between 1260 and 1360 nm upstream, 1440 to 1500 nm downstream, and 1550 to 1560 nm for cable-TV video.

To meet the rise in bandwidth demand, these systems will require upgrading. Some anticipate that TDM and CWDM (or even DWDM) will have to coexist in the same installed network fibers.³ To achieve this, work is underway within the standardization bodies to define filters that block non-GPON wavelengths to currently installed customers. This will require the CWDM portion to use wavelength bands far away from those reserved for GPON. Consequently, they will have to use the L-band or the C- and L-bands, provided video is not used (see Figure 1).

WATER PEAK CHALLENGES

Until a few years ago, manufacturers avoided the water peak region, or E-band, because it was a high-attenuation region. Today, however, optical fiber manufacturers have dramatically reduced losses in this region, and look forward to reducing them even further.

Some E-band advocates are trying to reduce losses as much as possible in hopes that some systems will be able to operate solely in this band. This is like erasing the highest peaks of the Rocky Mountains while neglecting the gentle valley and convenient passes below. Economically and environmentally, it is simply not feasible.

In fact, the E-band can really only be used as an extension of the O-band, so its limiting parameter is the 1310 nm loss value. Consequently, standardization bodies have cleverly defined low-water-peak fiber standards (ITU-T G.652D – IEC B1.3) such that attenuation at 1383 nm is equal or lower than that at 1310

nm. The result is a specification for 1383 nm in the range of 0.32 – 0.34 dB/km.

Transmission reach is limited by the wavelength with the highest attenuation. Therefore, to leverage a 1383-nm attenuation (water peak) lower than that at 1310 nm, one should not use the part of the wavelength band with higher attenuation. As shown in Figure 2, the extreme case of a fiber with no water peak leads to a reduction of the total transmission window by a quarter!

Some fiber manufacturers claim up to 12 percent more reach and up to 27 percent greater served area if “no water peak” fiber is used in place of “low water peak” fiber. While it makes for clever marketing, this statement is misleading. It is relevant only if the system operates ONLY in the water peak region (E-band) and does not use 1310 nm or below (O-band). No such systems exist in the real world – 1310 nm is one of the most commonly used wavelengths. Because the E-band is used as an extension of the O-band, its limiting parameter is the 1310 nm loss value.

Another argument in favor of “very, very” low water peak is the use of distributed Raman amplification in the C-band. In this scenario, the pump wavelength is in the 1440 nm region. However, expectations for Raman applications in the C-band are very low – EDFAs have proven far more convenient.

Raman amplification could be re-considered in the L-band, but then the wavelength pump would be in the 1485-nm-wavelength region where the influence of the water peak is extremely low. For example, reducing the 1383-nm peak from 0.32 to 0.30 dB/km would lead to an improvement of less than 0.001 dB/km at 1485 nm.⁴ At 1440 nm, the same 1383-nm reduction

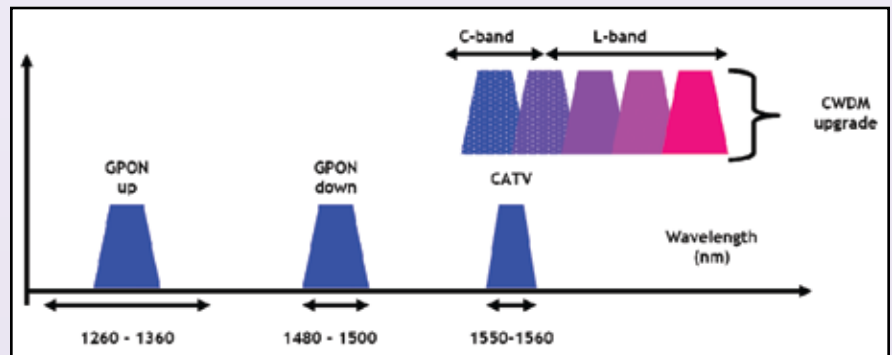


Figure 1. CWDM upgrade of GPON – wavelength plan.

The C-band has been a gift to optical communications, being a region of very low losses that facilitates very efficient optical amplification. The L-band represents a region of even lower losses, provided certain parameters are carefully mastered.

would lead to an improvement of 0.002 dB/km, which is also negligible.

Much of the industry believes that the era of pursuing perfection with no practical benefit has come to an end. Everything has a cost – even from an environmental point of view. Environmentally responsible companies are not supporting the race toward ever-decreasing water peak. It is a waste of effort as well as an unnecessary depletion of energy and drying gas, such as chlorine. These companies fully support the standardization bodies' logic that defines the right attenuation level as 1310 nm.

L-BAND CHALLENGES

Telecom is trending toward using the longer-wavelength bands. The C-band has been a gift to optical communications because it is a region of very low losses that also facilitates very efficient optical amplification. The L-band is a region of

even lower losses, provided that certain parameters are carefully mastered.

The most recognized drawbacks of the L-band are associated with microbend-induced losses. These additional losses must be maintained at very low levels throughout the fiber life by good design of the primary and secondary coatings.⁵ Additionally, some fibers have a specific trench-assisted design that significantly decreases these losses. The combination of these two techniques can decrease such losses by two orders of magnitude.⁶

Another drawback of the L-band is its macrobend sensitivity. For the same radius, optical losses caused by bending could be increased by several hundred percent at 1625 nm as compared to 1550 nm. Although bending is not a significant issue for backbone networks, it is a real challenge for FTTH architectures.

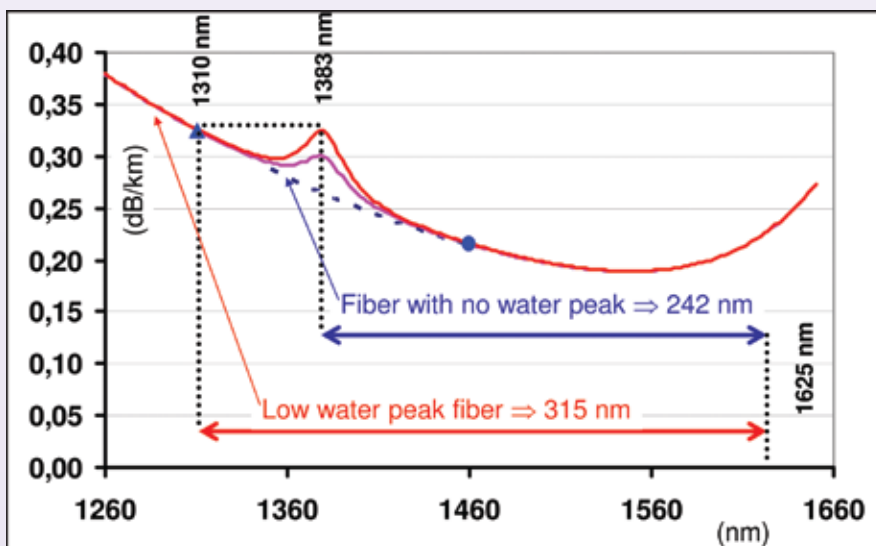


Figure 2. The advocated use of a fiber with “no-water-peak” contribution limits the usable wavelength band (in blue) by one quarter compared to the wavelength band offered by a G.652D-compliant fiber.

In FTTH networks, bend-tolerant-only fibers (fibers that only comply with the lower A grade of the new ITU-T standard G.657A) will not permit any upgrade at longer wavelengths. For example, the storage of two times one meter of G.657A-only fiber in a small footprint box (radius 15mm) results in a loss of 2dB at 1625 nm. That represents 10 percent of a PON budget – just for one box! It is only 0.2dB for G.657B bend-insensitive fibers. Telcos should be acutely aware of this issue and demand G.657A and B-compliant fibers.

NEW BATTLEFIELDS

In any technology development, the issues surrounding key challenges will change with time, dependent on the progress achieved and the requirements of the applications. For optical fibers, the main battlefields have been reducing background losses, mastering mechanical and geometrical parameters and reducing water peak.

But these are old fights. In each case, sufficient performance has been demonstrated to ensure high performance for today's and tomorrow's systems. The new battlefields are the macrobend and microbend losses associated with FTTH deployments and the need to use C- and L-bands in many future systems. **BBP**

About the Author

Laurent Gasca is a product line manager at Draka (www.draka.com), headquartered in Amsterdam, The Netherlands.

REFERENCES

1. G. Raybon, P.J. Winzer, C.R. Doerr “10 x 107Gbps electronically multiplexed and optically equalized NRZ transmission over 400km,” OFC, PDP32, 2006.
2. Technical Datasheet, Alcatel 1692 MSE.
3. H. Suzuki and al., “Wavelength-Tunable DWDM-SFP Transceiver with a Signal Monitoring Interface and Its Application to Coexistence-Type Colorless WDM-PON[,” ECOC, PD3.4, 2007.
4. Bredol M., Leers D., Bosselaar L. and Hutjens M., “Improved model for OH absorption in optical fibers,” Journal of Lightwave Technology, Vol. 8, Issue 10, pp 1536-1539 (1990).
5. “ColorLockXS, Draka Fibre Coating,” Application note, Draka Comteq, www.draka-fibre.com.
6. “A Comparison of Bend-Insensitive Single Mode Fibers,” Application note, Draka Comteq, www.drakafibre.com.