Increasing data traffic requires full spectral window usage in optical single-mode fiber cables

By Daniel Daems

Anticipating future needs

The optical fiber network infrastructures installed today will typically see four generations of transmission systems over the network's expected lifetime. As recent history has shown, the amount of data traffic these networks will carry will increase dramatically and continuously.

In order to cope with this increasing growth and anticipate the networks of tomorrow, a completely open spectral transmission window from 1260nm to 1625nm for data transmission and up to 1650nm for network monitoring is necessary in optical fiber cables.

Both ITU-T and IEC SC86A extended the fiber characteristics and the cable performance requirements to 1625 nm to guarantee cable performance at the higher wavelengths, where macro- and micro-bending loss may obscure the attenuation limits of cables under severe circumstances. The latest bend-improved fibers (G.657) support this optimization, particularly for demanding cable designs.

In principle, optical fibers offer a tremendous amount of potential transmission bandwidth or capacity, currently used for a wide range of applications, such as long-distance data transmission (e.g. internet traffic), fiber-to-the-home (FTTH) and cable television (CATV). Maximizing transmission capacity, requires new optimized fiber designs and communication techniques, which have been developed over the last decades in multiple steps, beginning with increased bit rates in telecommunications applications (TDM: Time Domain Multiplexing, currently standardized up to 40 Gb/s). (Figure 1.)

Starting at 1310nm, new wavelength transmission bands were introduced, first focusing on the 1550nm band for lower fiber attenuation. Finally the International Telecommunication Union (ITU) standardized transmission wavelength bands for optical communication over the entire wavelength range between 1260nm and 1675nm (O-, E-, S-, C-, L and U-band; shown in Figure 2), supporting Wavelength Division Multiplexing (WDM) techniques from 1260nm to 1625nm. Improved fiber designs and transmission techniques developed over the last three decades realized a 10-fold capacity increase every four years (Figure 2).

INCREASED NUMBER OF USERS
X INCREASED ACCESS RATES
X INCREASED SERVICES

BANDWIDTH EXPLOSION

- Increased number of users
- Globally, the number of internet users is forecasted to increase from 44% of the population in 2016 to 58% in 2021
- Increased access rates
- Globally, the average fixed broadband speed will grow 1.9-fold from 2016 to 2021, from 27.5 Mbps to 53.0 Mbps
- Increased services
- Social media, gaming, video on demand, HDTV, etc.

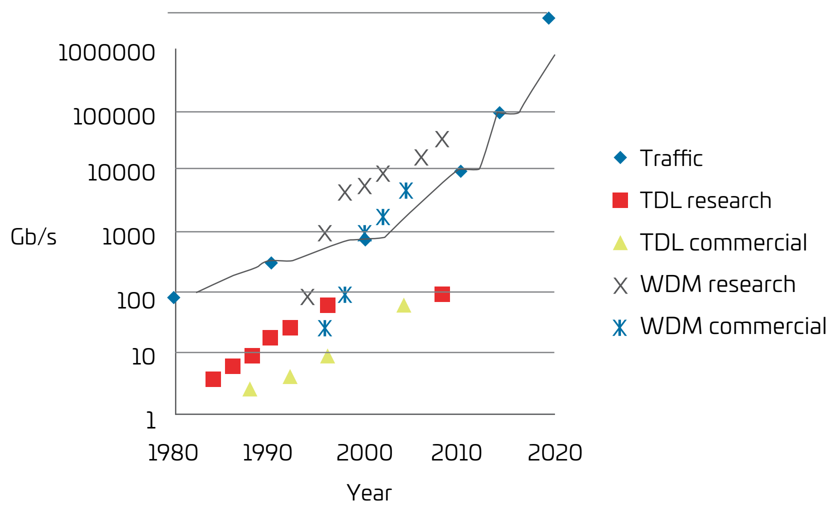

Figure 1: Points show the capacity of optical communication systems demonstrated in research and commercially; the line indicates the world's total traffic use. [1]

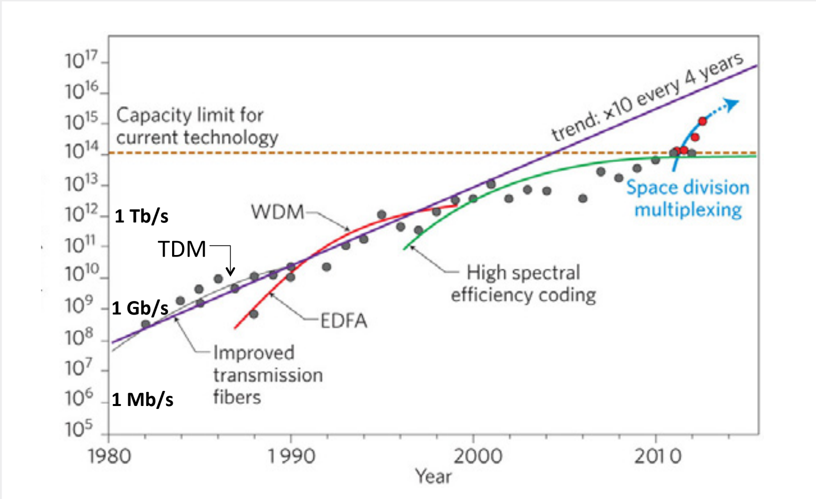

Figure 2: Transmission capacity development over the last three decades, starting with TDM (Time Domain Multiplexing) and WDM (Wavelength division multiplexing), resulting in a 10 times growth factor each 4 years [3].

Growth in data traffic and FTTH-networks

One of the most stable factors in today's communication world is the continued growth in data traffic. A multiplication of strongly increasing factors is leading to a bandwidth explosion[4]:

It is clear this huge increase in bandwidth demand needs to be supported by adequate optical transmission techniques. One of these techniques is WDM techniques, in particular focusing on the higher wavelengths: C- and L-band, up to 1625 nm (Figure 3).

Development of FTTH passive optical network (PON) systems also demands the largest available fiber optical transmission spectrum. Starting with GPON, relatively easy wavelength bands are used (upstream: 1290 – 1330nm; downstream: 1480 – 1500nm, with video overlay around 1550-1560nm). Discussions about XG-PON and in particular future NG-PON (WDM-PON) claim the outer ranges of the fiber spectrum (up to 1625nm). (Figure 4) System monitoring is foreseen at 1650nm. In order to guarantee future-proof applications, optical fiber cables currently installed should support full usage of all transmission bands.

Standardization of optical fibers and cables

The workhorse among installed fiber types is category G.652, the first edition being standardized in ITU-T in 1984 and developed over time to the most current sub-category G.652.D. This fiber category is by far the most widely installed fiber globally (Figure 5).

For several years ITU-T G.652 (cabled) fiber recommendation incorporated the C- and L-band extensions with (cabled) attenuation attributes at 1625nm resulting in a wide transmission spectrum from 1260–1625nm. This wide optical spectrum is used in optical telecommunication: Terrestrial Long Distance, Submarine, Metro-, CATV- and FTTH networks (PON and P2P).

Similar fiber types have also been standardized by the International Electrotechnical Commission. IEC SC86A not only standardized (bare) fiber types (60793-2-50 series), but also developed a full scale of cable types (indoor, outdoor, aerial and micro-duct cable) serving a extensive range of applications (60794 series of standards). In addition, IEC developed a wide variety of testing methods for cable types, acting globally as the main cable test methods.

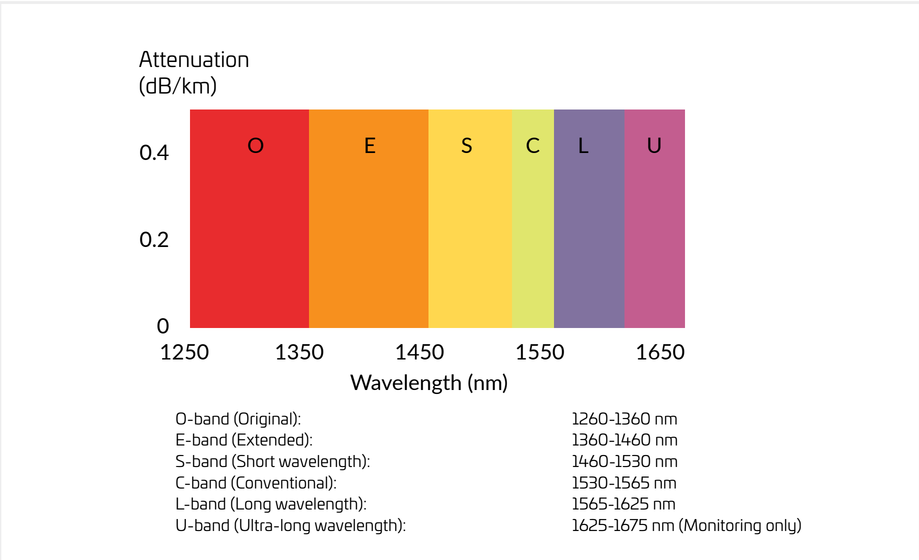

Figure 3: Typical spectral attenuation of single-mode fibers, highlighting different transmission bands, defined by ITU-T. [2]

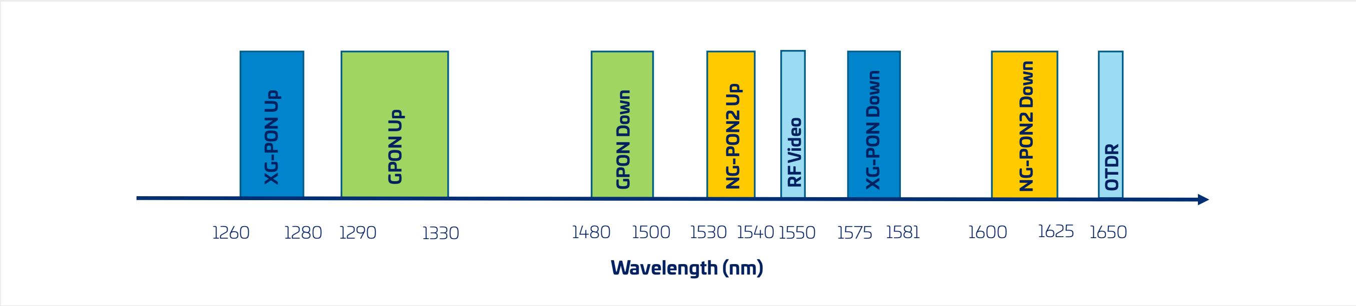

Figure 4: NG-PON2 spectrum
Source: Rec. ITU-T G.982.2 (12/2014)

Recently an important omission was observed in these IEC cable-type testing methods which required only 1550nm as the test wavelength. With the demand for wider wavelength ranges, such cable-type testing should be extended to also include 1625nm, a modification that needs to be incorporated in the IEC cable-type tests. This aspect is a serious issue, since two important cable loss phenomena can be active at the higher wavelengths: macro-bending and micro-bending loss.

Macro-bending loss is caused when the fiber is under constant bend radius. An optical signal, traveling through the fiber core, can lose a fraction of its power in a bent fiber; the tighter the bend radius, the more optical power is lost. Macro-bending loss in single-mode fibers is characterized by a relatively strong increase in loss above a certain wavelength (Figure 6).

Micro-bending loss is caused by longitudinal perturbations of the fiber, usually related to intense contact of cable materials to the optical fiber (e.g. shrinking effects in tight buffered fibers or less optimized loose tube cable designs). Micro-bending effects on fiber are investigated using sandpaper tests in which fiber under investigation is wound with large tension force. Micro-bending loss usually shows less wavelength dependency compared to macro-bending loss (Figure 6). Particularly in older cable types, increased loss could be present at higher wavelengths due to macro- and/or micro-bending effects, in particular at 1625nm (and certainly at 1650nm for monitoring applications). (Figure 7.)

Loss effects from macro- and micro-bending often manifest themselves in fiber cables under more extreme circumstances, e.g. at low temperatures when cable material shrinkage may induce fiber buckling in the loose tube, causing both macro-bending at small radii as well as micro-bending caused by pressure in the fiber against the tube wall (Figure 8).

In order to overcome such bending effects, a new category of bend-improved single-mode fibers was standardized by ITU in 2006: G.657 fibers. Of these fibers, sub-category G.657.A2 fibers offer the lowest bend losses (both macro- as well as micro-bending) while still being fully compatible with G.652.D fibers (Figure 8). These fibers can be used for a wide range of demanding applications and cabling structures, from access networks to fiber-to-the-antenna cables. A very special application for G.657 fiber cable is high optical power distribution, e.g. for central office patch cords (used for Raman gain applications, extensive DWDM or high power video overlay). Light stripped off from the fiber core under fiber bending, will be absorbed in the coating. At higher powers, this may lead to overheating of the coating and in extreme situations to catastrophic failures of the coating resulting in fiber breakage, or even worse within a central office, fire. G.657.A2 fibers (fully compatible with G.652.D fibers) offer the best bending immunity for such applications (Figure 9).

Such G.657.A2 fibers can also quite easily be used with reduced coating protection, e.g. 200μm coating diameter. Reducing the coating diameter usually increases the fiber sensitivity for micro-bending. However, in 200μm coated G.657.A2 fibers, the micro-bending sensitivity is still acceptable (comparable to that for 250μm coated G.652.D fiber (Figure 10), offering the interesting possibility of strongly reducing cable diameters, especially for high fiber count cables and micro-duct cable.

Cable with BI-SMF G657A2 guarantees open window

CommScope is aware of the necessity of future proof optical fiber cable. For that reason CommScope offers single-mode fiber cables with the option of open transmission window at 1625nm, enabled by G657.A2 technology.

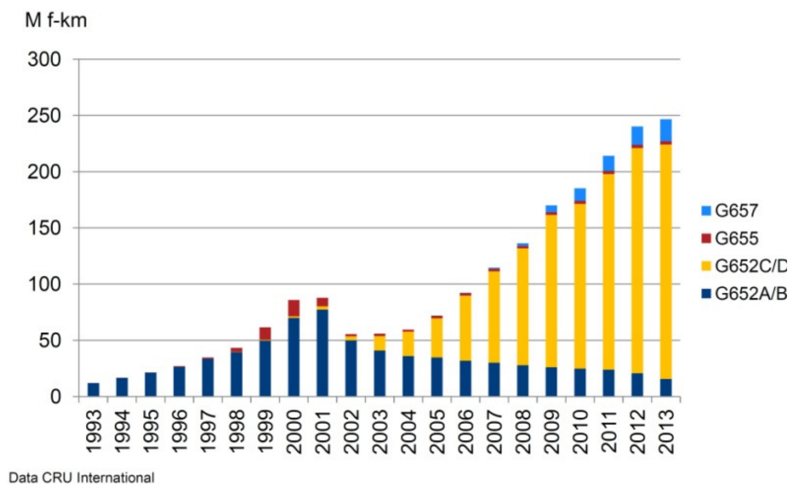

Figure 5: Yearly installed SMF by fiber category G652, G655, G657 [6].

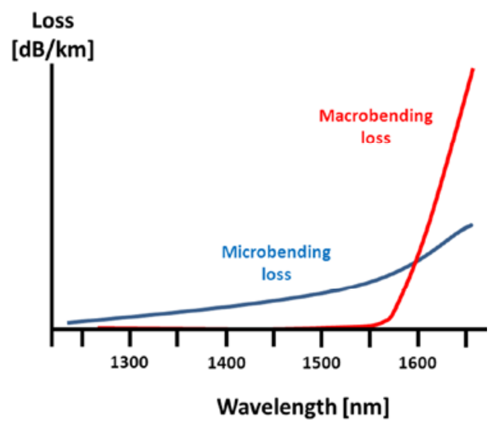

Figure 6: Example of macro- and microbending loss in G.652.D fiber.

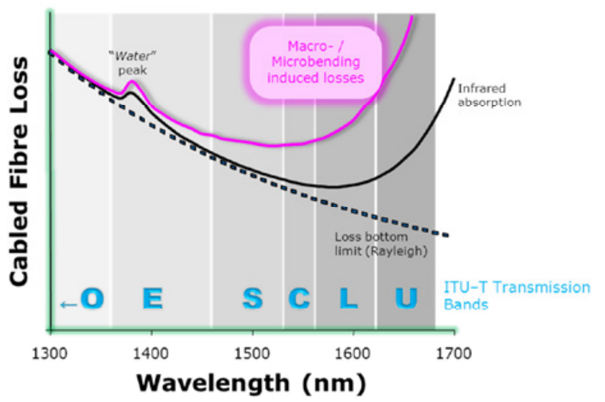

Figure 7: Example of total cabled attenuation including effects of macro- and microbending.

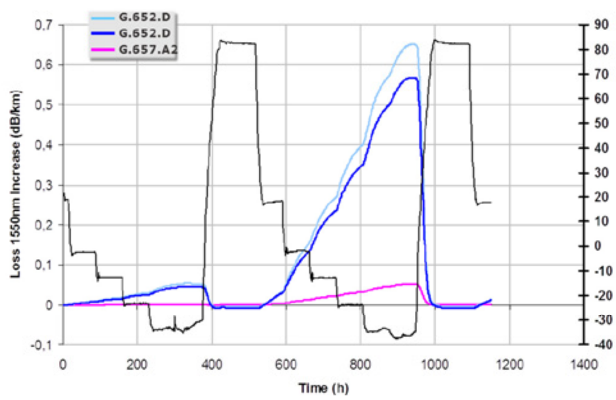

Figure 8: Temperature cycle test for demanding loose tube cable using G.652.D and G.657.A2 fiber.

The G.657.A2 fiber shows strongly improved performance. [7]

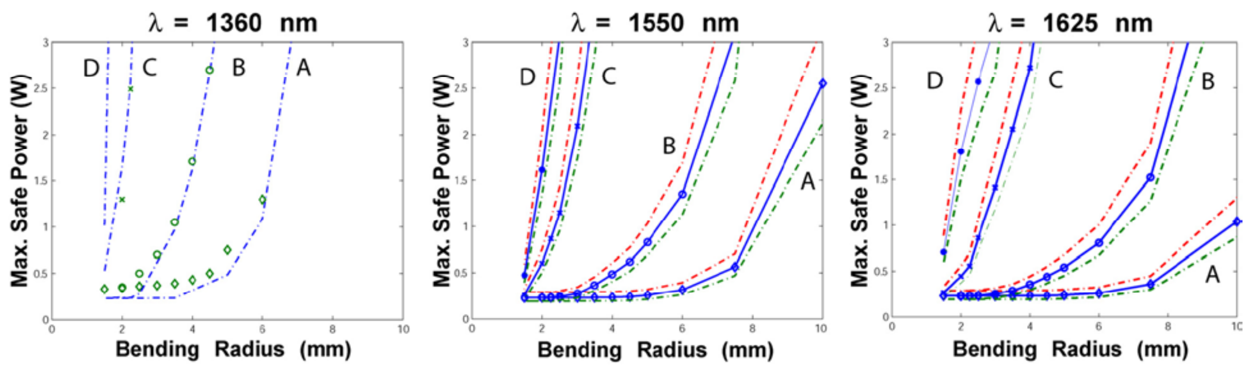

Figure 9: Left: From experimental test data at 1360nm, Maximum Safe Powers for 25-year lifetime are calculated as a function of bend radius, enabling a safe coating temperature of 80°C for four single-mode fiber (sub-) categories: A (G.652.D), B (G.657.A1), C (G.657.A2) and D (G.657.B3).

Middle and right: Extrapolated Maximum Safe Powers for 25-year lifetime at 1550nm & 1625nm. [8]

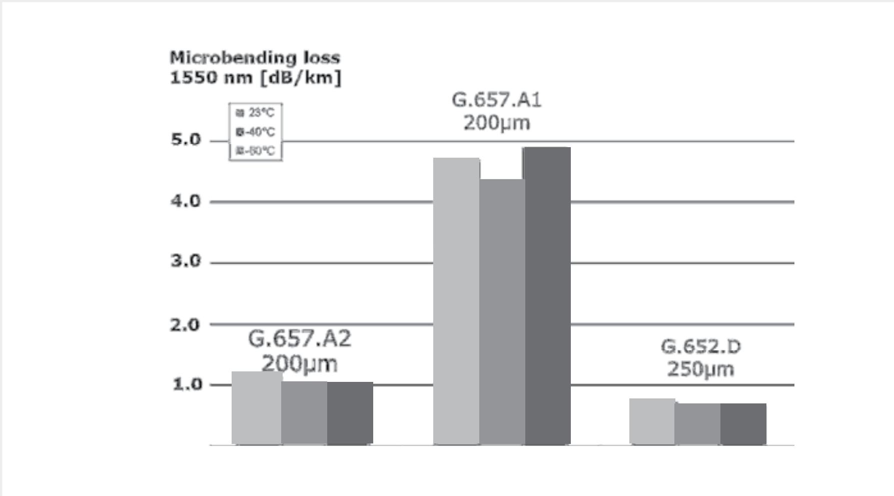

Figure 10: Micro-bending loss (sandpaper test method) for different bend-optimized G.657 fiber types equipped with 200µm coating diameter: G.657.A1 and G.657.A2 fiber. Reference G.652.D fiber equipped with 250µm coating diameter. 200µm coated G.657.A2 fiber shows superior behavior over 200µm coated G.657.A1 fiber, comparable to 250µm coated G.652.D fiber. [7]

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About the author

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Since 1988, Daniel Daems has developed optical fiber management systems and closures for outside plant applications.

Currently Fellow of the Global Standards Depratrment at Commscope in Belgium. Daniel was Chairman of the IEC SC86B (Fiber optic interconnecting devices and passive optical components) from 2009 till 2018. He is the Convener of the Cenelec (European standards) TC86BXA WG2 for fiber optic enclosures.

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WP-110966.2-EN (03/19)