Smart Optical Fibre Infrastructure

Advanced Low Loss Single-Mode ITU-T G.652.D Compliant Optical Fibre: An Innovation for the Foundation of the Outside Plant of Next Generation Broadband Networks

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Abstract

Optical fibre is the foundation of any optical network and so it is essential that the fibre deployed has the performance and capability required to overcome the challenges inherent to each scenario. Optical fibres offering an improved OSNR (Optical Signal Noise Ratio) through a low attenuation coefficient together with a very low PMD (Polarization Mode Dispersion) are certainly the preferred fibres to be deployed in terrestrial long-haul and metro networks because they provide a cost-effective solution to transport very high data rates (40 Gb/s, 100 Gb/s). Submarine networks, where design is not confined by ITU-T standards, may achieve further OSNR benefit from low attenuation, low PMD fibres with larger effective areas [1]. But in the outside plant of Next Generation Access Networks, there is a wide variety of technological challenges and a myriad of coexisting solutions that naturally raise the question as to the preferred or most optimized fibre to deploy. In this paper we examine both the challenges and trends that operators are facing in their access networks, exploring the attributes of the optical fibre that matter the most in the outside plant of Access Networks in terms of enabling a flexible and robust infrastructure capable of providing subscribers today with the broadband of the future.

1. NGA: A Long Term Investment

Next Generation Optical Access Networks differ depending on the FTTx topology and network technology selected (HFC, xDSL, P2P, TDM-PON, WDM PON). Optical access network deployments also vary widely by region and country, mainly due to the differences between the players (incumbent operators, alternative operators & MSO, utilities & municipalities) and their competitive, regulatory and economic environments. This is particularly visible in European countries where, despite the broadband targets set by the European Commission for the European Digital Agenda, each member state has its own broadband market specificity and, consequently, its own roll-out plan to meet the objectives set in the Digital Agenda.

Independent of these differences, Next Generation Optical Access Network deployments are, however, considered as a long term investment in an infrastructure dedicated to provide highly reliable, future proof and cost-efficient connectivity to subscribers for a steadily growing demand of capacity and bandwidth.

2. Meeting the Myriad of Access Network Challenges

During its deployment and operation lifetime, an optical access network is not expected to have a homogeneous structure. Its passive infrastructure will need to be capable of supporting the coexistence and migration of a variety of network technologies and services:

- The optical access network needs to be flexible in order to enable its operator to serve both residential users (low-end and high-end) and business customers with the services for which they are prepared to pay.

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- The passive infrastructure of the network also needs to be future proof and capable of supporting migration to higher data rates, as driven by adoption of progressively more advanced active equipment and the evolution of standards – e.g. from GPON to XGPON1 and further to NGPON2.
- The passive infrastructure needs to be able to support the coexistence of different system generations on the same fibre, e.g. GPON and XGPON1 (10GPON) [2].
- Depending on the geographic areas of deployment, an operator might choose to deploy different technologies and topologies in its access network – e.g. P2P in area of high density population and PON in medium density and rural areas – including PON with various splitting ratios and coverage distances.
- The operator may also change and adapt its network architecture over time depending on the growth of its customer take rate, e.g. by changing the splitters in the MDU basement to increase the splitting ratio in order to easily and cost-efficiently connect additional homes.
- An operator's deployment experience may result in a decision to change its connectivity and cable installation practices by increasing the use of pre-connectorised cables in the outdoor and/or indoor drop cabling portions of its net work, thereby reducing the labour costs and time needed to connect new customers.
- Especially in Europe, and according to the directive of the European Commission for open internet and net neutrality [3], the passive part of optical access networks needs to be technology neutral to enable infrastructure sharing between several operators
- Finally, as mobile broadband services significantly expand in data rate and coverage, operators are increasingly needing to leverage the optical access network as the infrastructure for the mobile backhaul service to connect cell sites.

To meet this variety of challenges, it is essential that the fibre deployed has the performance and capability to overcome the requirements inherent to each scenario. The fibre of choice will have to provide the network operators deploying Next Generation Optical Access Networks a flexible, robust and cost-efficient fibre infrastructure to enable them to pre serve their investment for the long term.

3. Fibre Loss Matters in the Outside Plant of Next Generation Access Networks

Next Generation Optical Access Network operators are keen to identify technological and architectural solutions that enable them to simplify their network and reduce the Total Cost of Ownership (TCO) while still satisfying their steadily growing bandwidth demand [4]. Solutions such as:

- Increased network coverage distances and optimization of the number of homes passed, especially on the fringe of the Central Office coverage areas.
- Increased split ratios in PON networks, e.g. from 64 to 128, 256 [6] or more.
- Extended system reach in medium density and rural areas, e.g. extending PON networks from 20 km to 60 km maximum fibre distance [7].
- Migration and convergence to Internet Protocol (IP) based networks.
- Reduction and consolidation of the number of Central Offices [8], which might ultimately increase access link lengths up to 100 km and subscriber coverage of 1000 customers per fibre feed [9].
- Utilisation of WDM technologies to increase network efficiency and enable a possible convergence of the access and metro networks.
- Minimization of the amount of active equipment to reduce network energy consumption [10].

To deliver the above evolution of architectures and systems requires ubiquitously improved link power budgets to enable better system margins [5].

The link power budget is the maximum allowable end to end signal loss from the Central Office right through to the customer's terminal in the customer's premises. Optical fibre loss (or attenuation) is a key factor contributing to such signal loss and so fibre loss particularly matters when network technology and architecture evolve as just described.

Therefore a single-mode ITU-T G.652.D compliant optical fibre with substantially reduced attenuation coefficient across the entire 1260 nm to 1625 nm operation wavelength spectrum greatly expands the network engineering possibilities. Low loss optical fibre delivers improved link power budget, thereby enabling increased subscriber coverage, higher PON splitting ratios, extended Central Office coverage to allow consolidation of redundant facilities, and migration and coexistence of different system generations operating on the same fibre.

In addition, future scenarios like convergence of metro and access networks, longer reach and higher splitting ratio at high data rate per user - possibly leading to very high transmission speeds in the feeder fibre of the PON network – will require particular attention to the link PMD. A low loss single-mode ITU-T G.652.D compliant optical fibre with a very low PMD coefficient is the optimal design to meet the requirements of these future scenarios.

4. Low Loss Single-Mode ITU-T G.652.D Compliant Optical Fibre

Today Corning's advanced low-loss fibre manufacturing technology delivers enhanced single-mode ITU-T G.652.D compliant optical fibre with a significantly reduced attenuation coefficient across the entire operational wavelength spectrum, i.e. from 1260 nm to 1625 nm, and a very low PMD coefficient. With its reduced attenuation and PMD coefficients, but while maintaining all the other optical attributes, - including the glass structure and geometrical characteristics - identical to legacy single-mode G.652.D compliant fibre, this new low loss single-mode ITU-T G.652.D optical fibre provides new advantages for network engineering and a solid foundation for Next Generation Optical Access Network deployments as well as the upgrade of existing networks.

Figure 1 compares the spectral attenuation curve of a low loss single-mode ITU-T G.652.D optical fibre to the equivalent spectral attenuation curve of a legacy ITU-T G.652.D fibres.

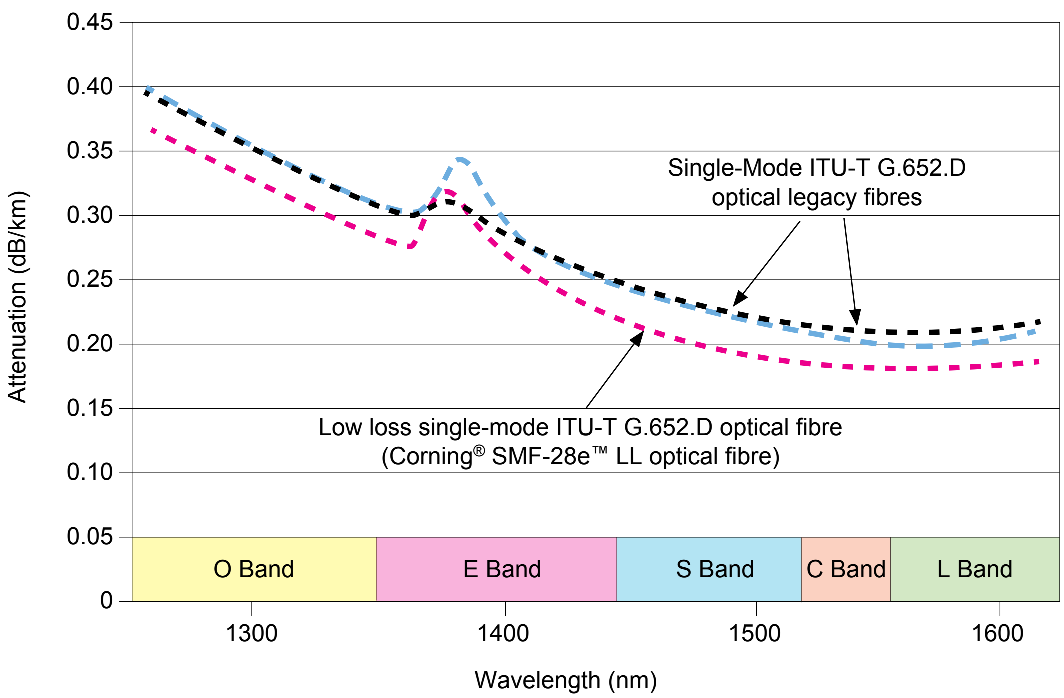

Figure 1

Low loss single-mode ITU-T G.652.D optical fibre offers premium non cabled fibre specifications for:

- Attenuation ≤0.32/0.32/0.21/0.18/0.20 dB/km at 1310/1383/1490/1550/1625 nm.
- PMDq (PMD Link Design Value) ≤0.04 ps/√km

Figure 2 compares the non cabled specified attenuation and PMDq values of low loss single-mode ITU-T G.652.D optical fibre with legacy single-mode ITU-T G.652.D fibres.

Being ideally suited for long-haul, metro and also access networks, low loss single-mode ITU-T G.652.D optical fibre enables the deployment of a seamless ITU-T G.652.D fibre based infrastructure with industry leading specifications for attenuation and PMD, to deliver better cost efficiency and reduced complexity for the all Next Generation Optical Network.

	Corning SMF-28e+ LL Fiber	G.652.D fibre A	G.652.D fibre B	G.652.D fibre C
1310 nm (dB/km)	≤0.32	≤0.34	≤0.33	≤0.35
1490 nm (dB/km)	≤0.21	≤0.24	not specified	not specified
1550 nm (dB/km)	≤0.18	≤0.21	≤0.19	≤0.21
1625 nm (dB/km)	≤0.20	≤0.24	≤0.22	≤0.23
PMDq ps/√km)	≤0.04	≤0.06	≤0.08	≤0.06

Figure 2

5. Low Loss Advantages for Access Network Engineering

5.1 Coexistence of GPON and 10GPON

Gigabit PON systems (G-PON and 1G-EPON) are now broadly deployed. To satisfy increasing bandwidth demand from residential users and business customers, the ITU-T standards body have standardized a 10 Gigabit capable next generation PON (XG-PON ITU-T G.987.1). To enable network operators to migrate customers of their existing GPON network to the higher speed services of 10GPON, thus preserving their investment in their existing fibre infrastructure, the ITU–T Recommendation G.987.1 addresses and provides for the coexistence of GPON and 10GPON on the same fibre through a wavelength band plan [2].

Figure 3 shows the operating wavelength allocation for GPON and 10GPON (XG-PON).

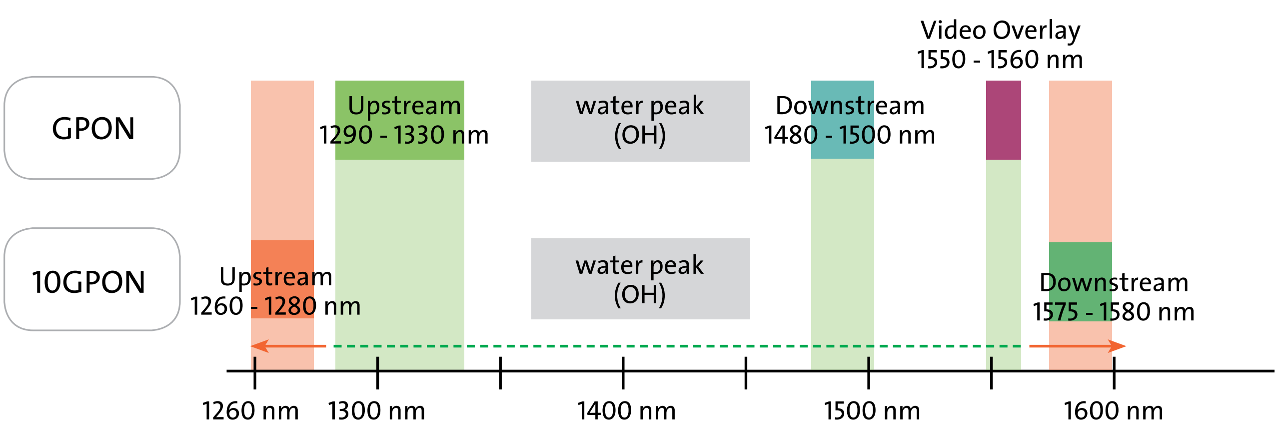

Figure 3

While GPON uses wavelengths from 1290-1330 nm for the upstream signal and from 1480-1500 nm for the downstream, 10GPON uses a broader spectrum of the fibre from 1260-1280 nm for the upstream and 1575-1580 nm for the downstream.

Current PON systems are designed using the 1310 nm attenuation level of legacy G.652.D fibre within the power budget calculations. However, at the 1260 nm to 1280 nm wavelengths assigned to the upstream Rec. G.987 (10GPON) signals the attenuation can be 0.07 dB/km higher than at 1310 nm [11]. When using legacy G.652.D fibre this will consume more of the available power budget, limiting the reach, coverage or flexibility of the whole system. However the attenuation of low loss single-mode ITU-T G.652.D optical fibre has been reduced significantly across the whole spectrum such that the attenuation at 1270 nm of new low loss ITU-T G.652.D fibre is close to the 1310 nm attenuation level of legacy G.652.D fibres. This enables a shift to 1260-1280 nm operational wavelengths and the coexistence of GPON and 10GPON on the same fibre with minimal compromise on network link design or flexibility.

5.2 Increased FTTH Subscriber Coverage Area

The maximum reach of a standard GPON system (ITU-T Rec. G.984.2) is 20 km. Network operators deploying GPON in high density areas and using 1:64 split ratios in Class B+ systems usually are limited to maximum link reaches in the range of 7 to 9 km. However, network operators are keen to optimize the number of homes passed by increasing the link distances in order to reach "not spot" customers on the fringe of the Central Office coverage areas.

Figure 4 shows how the coverage area of a Central Office can be increased by 19% simply by using low loss single-mode ITU-T G.652.D optical fibre (assuming an attenuation of 0.32 dB/km at 1310 nm for the low loss ITU-T G.652.D optical fibre compared to 0.35 dB/km at 1310 nm for legacy ITU-T G.652.D fibre).

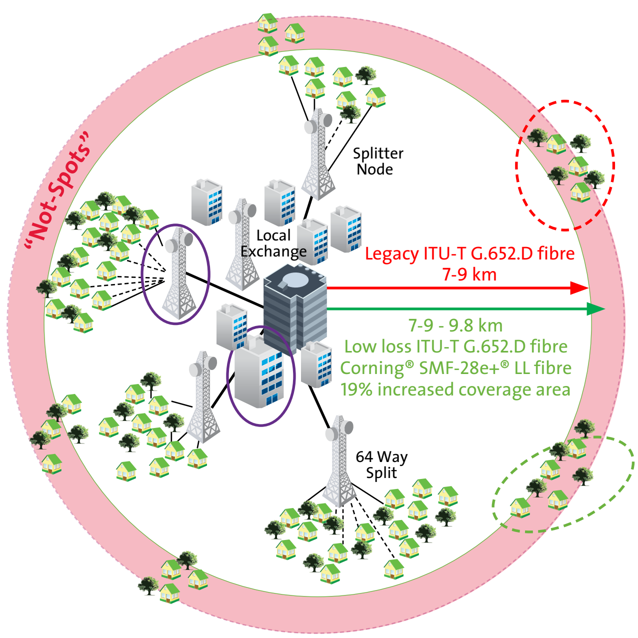

Figure 4

6. Next Generation Access Networks and Fibre Handling Performance

6.1 Splice-ability

Splice-ability of the fibre to be deployed in the optical access network is another key feature that needs to be considered in order to facilitate an easy and low cost initial deployment and to reduce the mean-time-to-repair in case of cable break later in the cable lifetime.

PON networks often deploy a primary splitter in a concentration point (aggregation node) and a secondary splitter in a cabinet on the roadside or footpath close to customer premises or in the building basement. Cables used in PON infrastructures have relatively low fibre count - in general up to 144 or 288 fibres in the feeder portion- and a progressively decreasing fibre count when moving further in the distribution and drop portions of the network. However experience shows that up to 7 splice points can be typically found on the link between the Optical Distribution Frame (ODF) in the Central Office and the last splitter level in the basement of the building.

In contrast, Point to Point (P2P) networks have less splice points, but usually require very high fibre count cables in the feeder portion of the network up to the aggregation point, with cables containing e.g. up to 576 to 720 fibres.

Networks operators that have commenced large scale deployments of FTTH are often confronted with the practice of installation companies sub-contracting the cable installation work to other installers, including to small local electrical contractors. This results in:

- fibres being spliced by installers with a low skill/experience level in terms of optical fibre fusion splicing,

- a large variety of different fusion splice machines used in the field, with the network operator having little control over the degree of maintenance of the machines.

With the glass structure and geometrical characteristics of the low loss single-mode ITU-T G.652.D optical fibre being identical to legacy G.652.D fibre, this new advantaged low loss G.652.D fibre intrinsically delivers a highly reliable splice performance on standard G.652 splice programs, without the need for using custom splice settings.

With this ease of splicing and equivalent splice performance to legacy G.652.D fibre, low loss single-mode ITU-T G.652.D optical fibre can be immediately deployed in access networks with no operator concerns about splicing related installation and cable repair issues.

6.2 Optical Fibre Choice and Outside Plant Micro-Cables

Operators are very keen on finding solutions that accelerate the deployment of FTTH networks by significantly reducing the civil infrastructure works and installations costs. For example by:

- Maximizing the utilization of current infrastructure including using available space in existing ducts such as copper cable ducts originally installed by telecom operators or ducts currently used for street lights, gas, sewers or power cables [12] [13] .
- Sharing the duct infrastructure with other operators.
- Utilisation of new digging methods with reduced construction size, for example mini or micro trenches.

These installation practices lead to fairly extensive utilisation of micro-ducts and micro-cables in the access network, especially in the distribution and drop segments of the Outside Plant (OSP) when moving closer to the customer homes. Depending on the cable specification requirements, it can often make sense to use ITU-T Recommendation G.657 category A1 single-mode optical fibre in order to cost-effectively meet the technical requirements of the optical fibre cable.

It appears, based on reported experiences from the field that single–mode optical fibre of the type sub-category ITU-T G.657.A1, which is specified to have improved macrobend performance at bend radii down to 10 mm, is the preferred G.657 fibre type for some micro-cable designs destined for installation in the distribution portion or last mile of access networks. Figure 5 illustrates the macrobend performance of a commercially available G.657.A1 product relative to a standard ITU-T G.652.D single-mode fibre.

The enhanced ITU-T G.657.A1 fibre illustrated offers not only solid macrobend loss performance, but also excellent splice loss results in the field due to its simple and robust glass design that enables easy and reliable fusion splicing using the conventional standard single-mode splice program available in any splice machine.

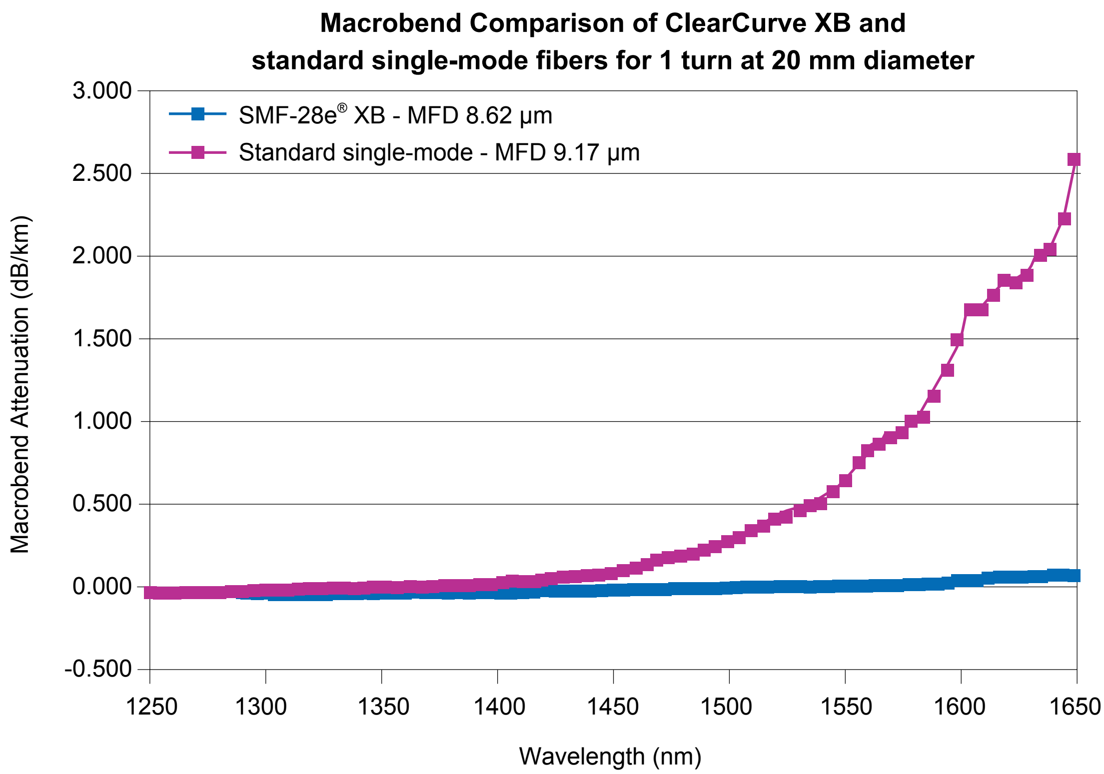

Figure 5

7. Summary

Next Generation Access Network deployments are considered a long term investment and therefore require a flexible, robust and cost-efficient fibre infrastructure to enable highly reliable and future proof subscriber connectivity while accommodating the steadily growing bandwidth demand.

In order to meet the challenges set by the diversity in network architectures, system technologies and deployment scenarios that are seen in today's, and will be seen in tomorrow's access networks, fibre loss really does matter in access network outside plant infrastructure.

Thanks to Corning's new low loss optical fibre technology, the industry now has available an enhanced low loss single-mode ITU-T G652.D optical fibre, featuring a substantially reduced attenuation coefficient across the entire 1260 nm to 1625 nm operation wavelength spectrum and a very low PMD coefficient.

Such advanced low loss optical fibre is the natural fibre of choice for the outside plant infrastructure of Next Generation Access Networks. With its industry leading specifications for attenuation and PMD, low loss single-mode ITU-T G652.D optical fibre is also optimised for long haul and metro networks, and thereby will enable a seamless and smart, highly advantaged ITU-T G.652.D fibre based infrastructure for all Next Generation Optical Networks.

8. References

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