Deployment Considerations for FTTH in Multiple Dwelling Units
White Paper

Optical
Fiber

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Introduction

Densely populated urban areas are being actively targeted for the next roll-out of fiber-to-the-home (FTTH) deployments. Implicit in this enterprise is to capture as subscribers a large proportion of the 700 million households occupying Multiple Dwelling Units (MDUs), i.e. flats and apartments, worldwide. Occupants of MDUs are anticipated to represent the majority of urban residents eventually subscribing to FTTH.

Early investigations by operators into the feasibility of deploying optical cable into MDUs have unveiled new constraints regarding installation techniques and deployments that must be taken into consideration. Although standards have been created to address access network constraints, specifically ITU-T Recommendation G.657, identifying two classes of fiber with improved macrobending performance, it is already apparent that performance in excess of this standard will be necessary to enable successful roll-out of FTTH into MDUs. This White Paper explains why performance beyond that defined in Recommendation G.657 is required to achieve significant deployment cost savings and discusses the implications for fiber design.

Constrained Deployment in MDUs

Typically, FTTH within an MDU will involve an optical cable link being installed between the building entry point and each subscriber within the MDU. The economics of maximizing ROI (return on investment) dictate that installation should be achievable quickly, using relatively inexperienced technicians, and by minimizing costs associated with "protecting" the fiber compared to deployments elsewhere in the network. This implies the following conditions;

- Flexible miniaturized cables capable of being maneuvred into corners and around obstacles to span the link to the subscriber in the most convenient and visually unobtrusive manner.
- Single operation to route the cable i.e. elimination of ducting to route the cable and provide protection from external interference.
- Rugged cable designs that can be treated just like copper cable, such as directly affixing the cable to the walls of the building using fast, low technology equipment e.g. a staple gun obtainable from retail hardware shops.

Some examples of the severe installation and routing found within buildings are presented in Figure 1. The common feature of all these examples is that the optical fiber contained within the miniaturized cable becomes confined in a bend radius radically smaller than is experienced by fiber in networks outside the building.

Figure 1. A montage of in-building installation and routing techniques that result in unusually tight bending for optical fiber.

Improved Bending Fiber for Access Network Installations

ITU-T Recommendation G.657 attempted to address the concern that installation practices exemplified in Figure 1 would lead to unacceptable levels of attenuation in conventional single-mode fibers complying to ITU-T Recommendation G.652. Table 1 indicates how the macrobending requirements of G.657 are tightened to address the more constrained environment of the access network. Improved macrobending has been demonstrated using a number of optical fiber design modifications, illustrated in Figure 2, such as increased core refractive index, reduced mode field diameter, depressed cladding and trench cladding.

	Tightest Bend Radius Specified (mm)	Specified Bend Loss 1550 nm (dB)	Specified Bend Loss 1625 nm (dB)
G.652 Table D	30 (100 turns)	n/s	≤1
G.657 Table A	10 (1 turn)	0.75	1.5
G.657 Table B	7.5 (1 turn)	0.5	1.0

Table 1. Tighter macrobending requirements demanded by Recommendation G.657 compared to Recommendation G.652.

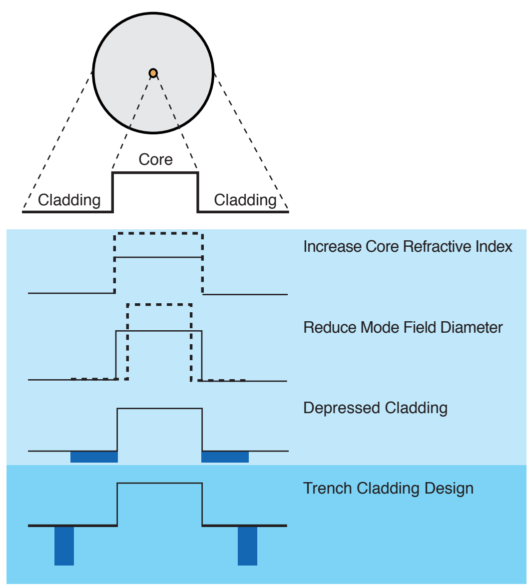

Figure 2. Alternative designs for improved macrobending performance to meet requirements of Recommendation G.657.

Fiber Performance in Constrained MDU Deployments

Table 1 indicates that compliance to Recommendation G.657.B implies capability to deploy in bend radii as low as 7.5 mm. However, as deployments in MDU started to roll-out it became evident that optical power budgets were becoming immediately challenged, even though fiber complying with G.657 was deployed. On investigation, it became apparent that the G.657 standard under-estimated the degree of bending that could be imparted by the installation approaches described earlier when using the flexible and visually discreet miniaturized cables that are regarded as ideal for within building deployment. Cables being bent through 90º into corners and around obstacles were found to be routinely imparting bend radii as low as 5 mm on the constituent fiber. When the bending introduced to the optical fiber due to stapling an indoor cable directly to the wall was considered, partial bends in the optical fiber of were also identified with the induced bend radius also reaching 5 mm. The degree of bending induced by stapling was confirmed by x-ray analysis of a cable affixed by this technique, see Figure 3. Bottom line, if miniaturized cable will experience 90º turns and/or stapling, performance at 5 mm is absolutely required.

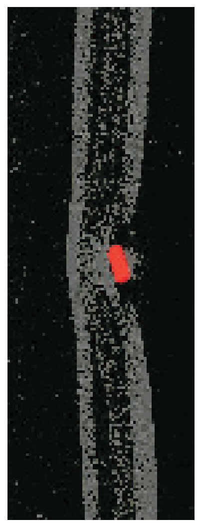

Figure 3. X-ray of bending of fiber in miniaturized cable due to direct affixing using stapling technique.

Even for fiber meeting the requirements of ITU Recommendation G.657, that has been designed using one of the conventional techniques shown in Figure 2, macrobending losses down at 5 mm bend radii can be far above the level that is tolerable for MDU installations. Figure 4 extrapolates the G.657 specification to predict performance to 5 mm radius. At 5 mm radius, this extrapolation indicates bend loss per full turn of >10 dB for G.657.A and >1 dB for G.657.B at 1550 nm. In comparison, specification for Corning's ClearCurve™ optical fiber, a G.657.A, G.657.B and G.652.D product designed specifically to meet the challenges of MDU deployment, is an order of magnitude improved, ≤1 dB/turn at 1550 nm. This represents a truly bend insensitive macrobend capability that is ideal for operation in MDU applications.

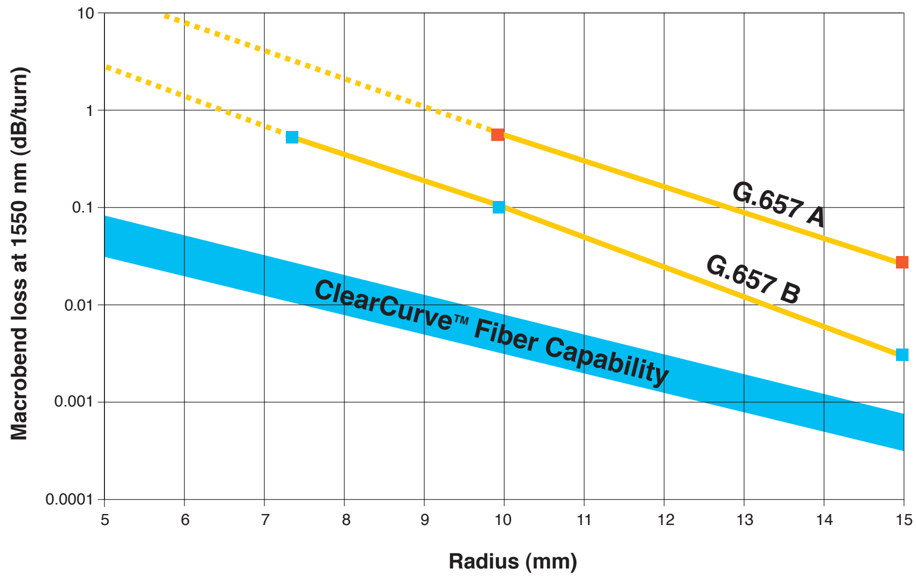

Figure 4. Extrapolation of ITU-T Recommendation G.657 performance to 5 mm and comparison with Corning's ClearCurve optical fiber.

Considering that the optical power budget within the MDU (after the intrinsic fiber attenuation, losses for splicing and conectorisation and margin for maintenance and repair has been extracted) may be as little as 0.5 dB for the type of multiple bending events illustrated in Figure 1, it is readily apparent that fibers only just conforming to the G.657 standard will be unsuited to demands of the MDU FTTH deployment.

The necessity of deploying an optical fiber that not merely complies with the G.657 standard but exceeds this performance and supports deployment to 5 mm bend radius was evidenced by a Corning study comparing the impact of stapling an indoor miniaturized cable containing commercially available G.657.A, G.657.B and G.652.D complaint fiber with a chemically doped trench cladding with the same cable design containing ClearCurve optical fiber. Figure 5 demonstrates the increase in cumulative loss induced by twelve incremental staples for the two fiber types.

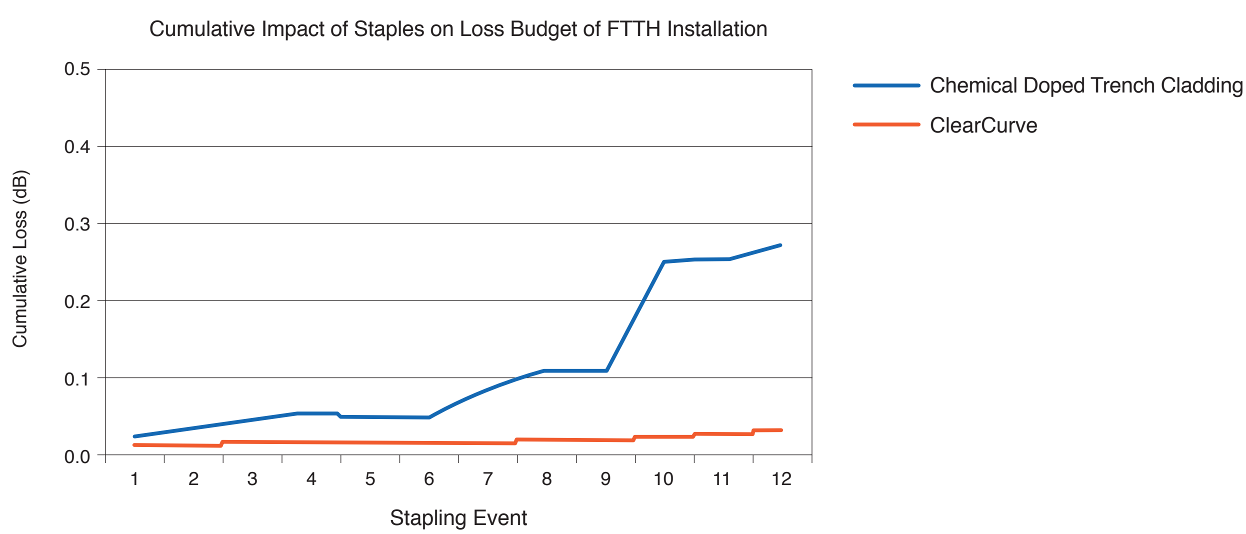

Figure 5. Comparison of bend loss due to incremental stapling in miniaturized cables.

The chemically doped trench cladding fiber, as well as suffering a significantly greater average loss per staple, has a much wider distribution of possible loss per staple, being susceptible to occasionally very severe incremental loss events resulting in a "perilous" staple of >0.1 dB, a feature entirely absent from the ClearCurve fiber which is designed and specified to provide excellent bending loss to 5 mm induced bend radius. With typical links in MDUs from basement to subscriber featuring several tens of staples, not to mention several 90º bends to navigate around corners and through walls, an installer is highly likely to encounter enough perilous staples to challenge the power budget of a link with only 0.5 dB margin for induced bend loss. Since optical signal testing would only follow the completion of the installation, and would not be monitored staple by staple as in the described test, full rework of the imperilled cable would be the probable outcome of applying the chemically doped trench cladding fiber to this application. Note this study was performed using round staples that are sanctioned by some FTTH network operators. The substitution by flat staples can lead to even more severe losses and the control of staple type in the field may be difficult for the network operator to impose.

Consequently, the conclusion is drawn that even G.657.B macrobending performance is insufficient to meet the stringent challenges of FTTH installation in MDUs. Enhanced optical performance to 5 mm bend radius is a requirement for this application space.

Mechanical Reliability Considerations

Having established that 5 mm bend radius is a necessary requirement for fiber installed in FTTH installations within MDUs, and that Corning's ClearCurve optical fiber is optically capable of operation in this confined deployment, it is also necessary to consider the mechanical reliability of fiber in this situation. Corning's White Paper WP1282, "The Mechanical Reliability of Corning Optical Fiber in Small Bend Scenarios" describes in detail Corning's use of a long established and accepted model for determining the failure probability of lengths of fiber subjected to multiple stress events of either tension or bending. This model is then applied to the particular situation of relatively short lengths of fiber constrained in very tight bends. It is important to appreciate that only the length of fiber actually placed under bend is susceptible to stress induced fatigue that may lead to risk of failure. For context, a full 360º turn of 5 mm radius consists of only 31 mm of fiber under bending stress. Since a failure over a 20 year lifetime requires the coincidence of a partial tight turn (e.g. around a corner or induced by a staple) with a highly infrequent, low initial strength flaw that fatigues to below the installed stress over the installation lifetime, it is perhaps unsurprising that the failure predicted by the model per full 360º turn of 5 mm radius is just 3 parts per million. This failure rate can straightforwardly be scaled up to the probability of failure per subscriber or per network by considering the number of corners required to negotiate the typical path to the subscriber and the frequency of stapling points necessary to affix the cable in place. Note this methodology assumes that fibers under bend endure stress that is only generated by the bending of the fiber and no additional tensile stress is present. Cable designs or installation practices that cause significant tensile load to be transferred to the fiber as the cable negotiates corners can lead to elevated rate of mechanical failure and should be disallowed.

As the predicted failure rate is so low and the installed fiber in MDU is very accessible in case of failure following installation, it is concluded that the approach of embracing miniaturized cables with fiber performance exceeding the requirements of Recommendation G.657.B and allowing installation techniques that constrain sections of the fiber to bends as low as 5 mm is fully justified.

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