Issue date: 11/07
Supersedes: 03/07

BendBright^{XS} Single Mode Optical Fibre

Enhanced low macrobending sensitive, low water peak fibre
Product Type: G.652D, G.657A&B
Coating Type: ColorLock™ and Natural

Draka Comteq BendBright^{xs} fibre combines two attractive features: excellent low macro-bending sensitivity and low water-peak level. Together they allow unlimited use of the whole telecom wavelength window for a great variety of applications. This next generation behavior has been obtained by adding a trench with a lowered refractive index in the cladding area preventing the optical field to escape. This has been designed in such a way that no compromise has been made with respect to the main tranismission parameters.

Apart form its use in office installations, as patch cords and/or interconnection cables, the use of the BendBright^{xs} in Fiber-to-the-Home networks offers significant added value to the network installers. Bend radii in fibre quidance ports can be reduced as well as minimum bend radii in wall and corner mountings. As the fibre is very forgiving for installation errors, reduced demands for the skills of the installation engineers may further reduce the costs. Its enhanced macrobending behaviour further guarantee that the 1625 nm window (L-band) will be available for future use in this bandwith hungry environment.

Draka Comteq's Advanced Plasma and Vapor Deposition (PCVD and APVD™) manufacturing process ensures the highest quality and purity of fibres. Proprietary ColorLock™ coating process further enhances the performance, durability and reliability of the fibre, even in the harshest environments.

The fibre fully complies with or exceeds the ITU-T Recommendation G.652.D, G.657A&B and the IEC 60793-2-50 type B.1.3 Optical Fibre Specification and is backwards compatible with all other G.652 fibre used in current optical networks.

Features Benefits	
• Low macrobending loss in the 7 to 15 mm bend radius range	• Allows shorter radius storage of fibre over-length leading to more compact installations • Is more forgiving for installation errors in fibre managements systems and/or splice protection devices
• Compatibility with other G.652 single mode fibre installations	• The BendBright^{xs} can be spliced with similar settings of the fusion splice programs as applied for other G.652 fibre • Low loss splicing of BendBright^{xs} to other G.652 fibres can be done with standard fusion splicers
• Low bending loss at partial bends in the mm bend radius range	• Allows for tight in-building installations • Allows for small volume patch panel installations • Prevents fibre coating degradation in case high power pump systems are used in up-grading scenarios
• Low micro-bending loss	• Allows for highly demanding cable designs including ribbons

Key Industry Leading Milestones	
2002	BendBright G.652B introduced; industry leading bend-insensitive single mode fibre
2005	BendBright G.652D introduced; allowing use of both E-band and L-band for low bend radius telecom applications
2006	AT&T awarded Draka Comteq with award for Technical Innovations for drop cable containing BendBright fibre
2006	BendBright^{xs} introduced; the first commercial fibre fully compliant with G.652D and G.657A&B

Draka Comteq | Optical Fibre

Netherlands:
Tel: +31 (0)40 29 58 700
Fax: +31 (0)40 29 58 710

France:
Tel: +33 (0)3 21 79 49 00
Fax: +33 (0)3 21 79 49 33

USA:
Tel: +1 828 459 8446
Fax: +1 828 459 8267

Email: fibresales@draka.com
Website: www.drakafibre.com | www.draka.com

Draka

Draka Comteq | Optical Fibre

Issue date: 11/07
Supersedes: 03/07

BendBright^{XS} Single Mode Optical Fibre

Enhanced low macrobending sensitive, low water peak fibre
Product Type: G.652D, G.657A&B
Coating Type: ColorLock™ and Natural

Optical Specifications (Uncabled fibre)

Attenuation	**Max. Value (dB/km)**
Attenuation at 1310 nm	0.33 – 0.35
Attenuation at 1383 nm H2 aged*	0.32 – 0.35
Attenuation at 1460 nm	0.25
Attenuation at 1550 nm	0.19 – 0.20
Attenuation at 1625 nm	0.20 – 0.21

** Hydrogen aging per IEC 60793-2-50, type B.1.3*
Other values available on request.

Attenuation vs. Wavelength

Maximum attenuation change over the window from reference

Wavelength range (nm)	**Reference λ (nm)**	**Change (dB/km)**
1285 - 1330	1310	≤ 0.03
1525 - 1575	1550	≤ 0.02
1460 - 1625	1550	≤ 0.04

Attenuation Uniformity

No point discontinuity greater than 0.05 dB at 1310 nm and 1550 nm.

Attenuation with Bending

Number of Turns	**Mandrel Radius (mm)**	**Wavelength (nm)**	**Induced attenuation (dB)**
10	15	1550	≤ 0.03
10	15	1625	≤ 0.1
1	10	1550	≤ 0.1
1	10	1625	≤ 0.2
1	7.5	1550	≤ 0.5
1	7.5	1625	≤ 1.0

Cutoff Wavelength

Cable Cutoff wavelength	≤ 1260 nm

Mode Field Diameter

Wavelength (nm)	**MFD (µm)**
1310	8.5 – 9.3
1550	9.4 – 10.4

Chromatic Dispersion

Zero Dispersion Wavelength (λ_0):	1300 - 1324 nm
Slope (S_0) at λ_0:	≤ 0.092 ps/(nm^2.km)

Polarization Mode Dispersion (PMD)

	(ps/√km)
PMD Link Design Value**	≤ 0.06
Max. Individual Fibre	≤ 0.1

*** According to IEC 60794 -3, Ed 3 (Q=0.01%)*

Geometrical Specifications

Glass Geometry	
Cladding Diameter	125.0 ± 0.7 µm
Core/Cladding Concentricity	≤ 0.5 µm
Cladding Non-Circularity	≤ 0.7 %
Fibre Curl (radius)	≥ 4 m

Coating Geometry	
Coating Diameter	242 ± 7 µm
Coating / Cladding Concentricity	≤ 10 µm
Coating Non-Circularity	≤ 5 %

Lengths	Standards lengths up to 25.2 km

Other lengths available on request.

Mechanical Specifications

Proof test

The entire length is subjected to a tensile proof stress > 0.7 GPa (100 kpsi); 1% strain equivalent.

Tensile Strength

Dynamic tensile strength (0.5 meter gauge length):

Aged*** and unaged:	median > 3.8 GPa (550 kpsi)

*** Aging at 85°C, 85% RH, 30 days

Dynamic and Static Fatigue

Dynamic fatigue, unaged and aged***	$n_d > 20$
Static fatigue, aged***	$n_s > 23$

Coating Performance

Coating strip force unaged and aged****:

- Average strip force:	1 N to 3 N
- Peak strip force:	1.3 N to 8.9 N

**** Aging:

- 23°C, 0°C and 45°C
- 30 days at 85°C and 85% RH
- 14 days water immersion at 23°C
- Wasp spray exposure (Telcordia)

Environmental Specifications

Environmental Test	**Test Conditions**	**Induced Attenuation at 1310, 1550 nm (dB/km)**
Temperature cycling	–60°C to 85°C	≤ 0.05
Temperature-Humidity cycling	–10°C to 85°C, 4-98% RH	≤ 0.05
Water Immersion	23°C, 14 days	≤ 0.05
Dry Heat	85°C, 30 days	≤ 0.05
Damp Heat	85°C; 85% RH, 30 days	≤ 0.05

Typical Characterisation Values

Nominal Zero Dispersion Slope	0.087 ps/(nm^2.km)
Effective group index @ 1310 nm	1.467
Effective group index @ 1550 nm	1.467
Effective group index @ 1625 nm	1.468

Rayleigh Backscatter Coefficient for 1 ns pulse width:

@ 1310 nm	–79.1 dB
@ 1550 nm	–81.4 dB
@ 1625 nm	-82.2 dB

Median Dynamic Tensile Strength	5.3 GPa (750 kpsi)

(Aged at 85ºC, 85% RH, 30 days; 0,5 m gauge length)

Draka

Draka Comteq | Optical Fibre

Issue date: 10/07
Supersedes: 08/06

Application Note

BendBright^{XS} : Macrobending improved single mode fibre

0. Introduction

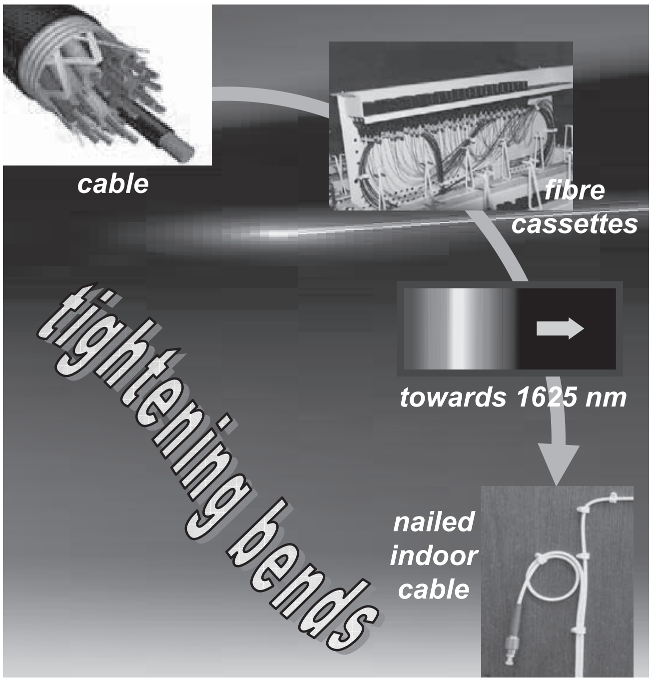
The BendBright series of macrobending improved single mode fibres (SMF) for telecom networks answers the market demand for bend-optimized SMF. Especially the ***BendBright***^{xs} shows perfect performance for the stringent needs in modern Fibre-to-the Home (FttH) networks or in more general access networks ***(XS=access)***. The aim of this Application Note is to support the user in the various applications of ***BendBright***^{xs} in telecom cables and networks, especially as they apply to the mixed use with conventional SMF. This Note starts with an overview section on the growing impact of macrobending loss throughout the years and the importance of backwards compatibility with the SMF applied in the “installed base” networks. Sections 3, 4 and 5 describe the particular issues related to *macrobending*, *microbending* and fibre *connection*, respectively. The final section covers lifetime aspects and some miscellaneous subjects. Specific fibre data and detailed specifications can be found in the *product datasheet*.

1. Macrobending loss: growing impact

For *telecom networks* bend loss has hardly been an issue for many years. Bending the fibre into a helical path is needed to create fibre over-length allowing cable elongation during installation and a suitable temperature operating window. This requirement was met quite easily. Bend radii well over 100 mm did not put high demands on the fibre bend loss. A further requirement was in the need to have storage of the fibre over-length in the splice enclosures along a route. The well-known “100 turns” requirement was created to represent the total number of fibre storage loops in a route. Radii of interest decreased to 30 mm, but for a limited length only. A more severe tightening occurred from the increase of operational wavelength into the long wavelength 1625 nm band. The associated extending optical field width at higher wavelengths makes the fibre more sensitive to bending. This ended up in the ITU-T Recommendations and IEC standards with the current requirement of a maximum added loss of 0.1 dB at 1625 nm for 100 turns with a 30 mm radius.

First generation bend performance improvements were addressed by standard single mode fibre (SMF) with its simple step-index profile of the core. The only measures taken by the fibre manufacturers were the gradual decrease of the nominal mode-field diameter (MFD) at 1310 nm down to about 9 µm and an increase of the average cable cut-off wavelength to a value not far below the lower limit of the operating wavelength window. These transitions were supported by narrowing production tolerances allowing prevention of worst case fibres.

The minimum bend radius of 30 mm has had a big impact. In most fibre management systems this minimum radius can be recognized in storage cassettes as well as in entrance and exit guides. More or less, the 30 mm radius has been considered as being a “natural law” which should not be violated. However, this situation has come to an end.



Component *volume* is becoming more and more a decisive factor in telecom offices, in cabinets and especially in access points and customer connection boxes in fibre-to-the-home networks. Smaller bending radii may reduce component size and lower the total ***cost*** of ownership further.

Another issue that developed is the ability of the fibre to cope with installation errors like short radius partial bends and/or "kinks" in the fibre. For higher level networks these are usually prevented by requiring well trained installation crews and/or by costly commissioning procedures. This is no longer affordable in the optical access networks, where labor and productivity impacts are much heavier due to the many splitting points and the frequent network changes inherent to the nature of direct service delivery to individual end customers. Fast, efficient and ***low cost*** installation is of even more importance here.

2. Backwards compatibility and compliance with international standards

In the development of low bend loss SMF, Draka Comteq has considered backwards compatibility a key requirement for network operators. Usually low bend loss is realized by using core modified profiles or by using the simplest approach, the "high delta" SMF (e.g. pay-off fibres used in military applications). In this last case, the refractive index step of conventional step-index SMF is increased significantly with a simultaneous reduction of the core size. The resulting low MFD (5 to 6 µm) is hardly acceptable for applications in telecom networks due to the mismatch with the SMF *installed base.* Apart from technical problems with increased coupling losses, an accompanying ***cost*** factor is in the need for precise registration of the use and stock of these cables as they should not be mixed with conventional cables.

The first generation of bend loss improved SMF, Draka Comteq's classical BendBright™ ESMF, referred to here as BendBright, was launched in 2002. Its concept is based on the selection process of standard fibres in combination with some specific in-process conditions. As a subset of SMF, BendBright fibres are fully backwards compatible with SMF in all aspects since they are part of the standard product line.

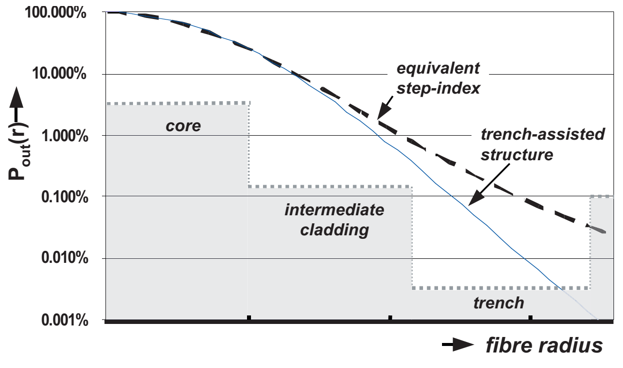


Fig. 1 Trench-assisted ***BendBright***^{XS} index profile (dotted line) and modeled fundamental power ($P_{out}(r)$ in %) propagating outside radius r for this profile and for an equivalent step-index profile
(Note: 0.5 % power loss corresponds with 0,02 dB)

For the ***BendBright***^{xs}, targeting also the tough requirements of the access network application, the condition of backwards compatibility is also maintained. Although this restricted the development process severely, it showed that the slight reduction of the MFD to an average value of about 8.9 µm together with the addition of an optical field confining *trench in the optical cladding* just outside of the core (see Figure 1 and Ref. [1]) provided the required significant bend loss improvement.

As a result, the trench-assisted ***BendBright***^{xs} can be mixed with conventional standard SMF, Draka Comteq BendBright and/or ESMF, without violating the requirements for practical installation, maintenance or operation of the optical network.
Referring to international standards, the trench-assisted ***BendBright***^{xs} is fully compliant with the current ITU-T G.652D Recommendation and the complementary IEC standard 60793-2-50 type B.1.3. With respect to the macrobending loss requirements, it is evident that ***BendBright***^{xs} shows characteristics far beyond these standards values. For this characteristic it provides full compliance with the ITU-T G.657 recommended bend-insensitive SMF classes. It is superior with respect to the "class A" performance and even coincides with the much more stringent "class B" requirements as indicated at 1550 nm in Figure 2.

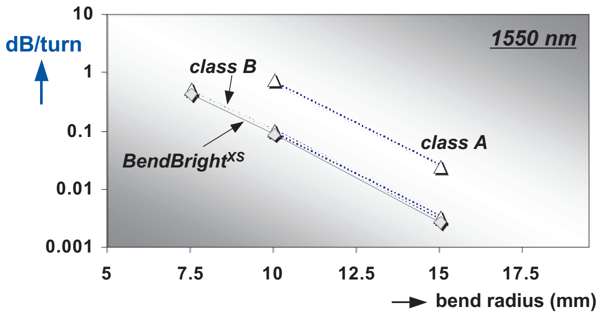


Fig. 2 ***BendBright***^{XS} complies with the ITU-T G.657 Recommendation on bend-insensitive SMF for both class A and class B

3. Macrobending loss

Low macrobending loss is needed

i) for storage of fibre, cord or cable over-length in patch-panels or in splicing cassettes and
ii) in case of single low radius bends as occurring in entrance and exit guides of fibre management systems, in indoor cable installations or due to maltreatment of the fibre (e.g. “stapling” or “nailing” the indoor cable).

For SMF, a commonly applied specification for bending loss is in the added loss per turn at a given wavelength. This loss increases *linearly* with the number of turns, so the specified loss for any number of turns can be calculated quite easily. As SMF bend loss increases with wavelength, the specification at the highest envisioned wavelength, i.e. 1625 nm is most critical. For applications where 1550 nm is considered as the highest operational wavelength a specification at this wavelength suffices. For ***BendBright^{xs}***, the loss at both wavelengths has been specified. The ratio between the losses at both wavelengths is not constant but depends on the bending radius. For 15 mm radius this ratio is about 5 and for 7.5 mm it has decreased to 2.5.

In Figure 3 an overview is given of the bend loss specification of ***BendBright^{xs}*** compared with classical BendBright, standard ESMF and the ITU-T G.652D Recommendation. Improvement is clearly visible and ranges up to a factor of 100 at a 15 mm radius.

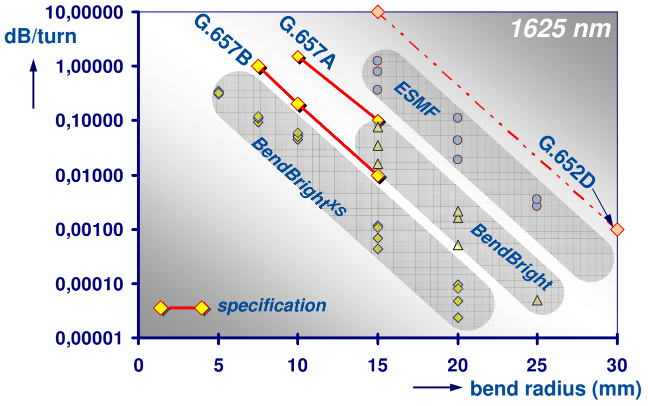


Fig. 3 Comparative macrobending loss overview. The dotted curve represents the maximum bend loss of a SMF just answering the ITU-T G.652 specification at a 30 mm bend radius

In specifying bend loss in dB/turn, the user must take into account that the fibre length in the turn is linearly dependent upon the bend radius. This means that for storage of a fixed length at a lower bend radius a higher number of turns must be accounted for. In practice however, the required storage length is decreasing due to ongoing miniaturization of all components, including the connector patch panels and splicing sets.

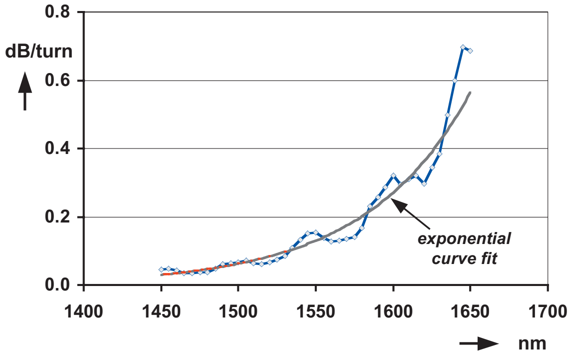


Fig. 4 BendBright^{XS} spectral macrobending loss for a R=7.5 mm test with 6 full turns in the test set-up.

A further effect to be highlighted has to do with the very nature of bend loss and might be of special relevance when considering low radius bends. The optical signal escaping from the core due to the bending of the fibre axis will be reflected at all interfaces with refractive index differences as e.g. the coating-cladding interface. Due to the curved reflection surfaces acting quite like a concave mirror, a significant part of the reflected power passes the core again and might interfere with the main power stream. As this interference is dependent upon bend radius and wavelength and might be either constructive or destructive, this results in a characteristic undulation (see Ref. [2]) of measured spectral bending loss curves as shown in Figure 4 for a 7.5 mm radius test. The undulation depth and the position of the tops are determined by the specific fibre geometry and core profile and by the specific fibre deployment. In spectral loss tests, as done for ***BendBright^{xs}***, simple curve fitting *(see IEC 60793-1-47 Macrobending loss test method)* results in the appropriate loss value. However, when measuring bend loss with an OTDR, quite large deviations can occur, especially in case of a single low radius bend where the undulation depth might be higher.

4. Microbending loss

Microbending loss reduces with a lower fibre MAC value, i.e. the ratio MFD/CO, just like the macrobending loss (see Ref. [3]). As extensive testing has shown, the optical field confining effect of the refractive index trench near to the core has a positive effect on microbending loss as well.

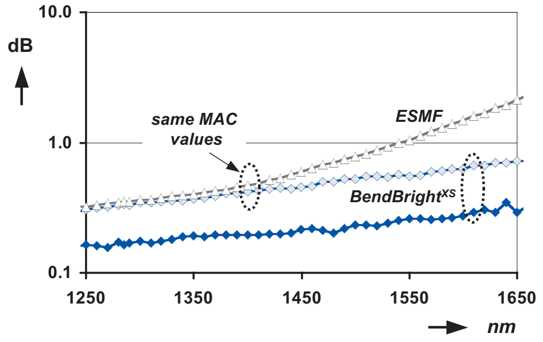


Fig. 5 Spectral loss curves for microbending tests on various fibres with similar coatings.

Figure 5 shows spectral loss curves from fibre subjected to the standard Draka Comteq micro-bending test. In this test, 400 m fibre is wound with high tension on a 60 cm diameter reel covered with low grain size sandpaper. The effect of the MAC value for ***BendBright***^{xs} shows from the two lower curves, whereas the effect of the trench alone shows from the comparison with an equal MAC value ESMF fibre test result. Note that the influence of the trench is not in the absolute height only, but also in the slope of the curve which favors the long wavelength behavior.

Microbending itself is a more or less un-defined deformation of the fibre axis for which some test methods are suggested in IEC Technical Report TR 62221. Other test methods have also been applied to evaluate the losses originating from micro-deformations as can occur in practice. Some examples are the “pin-array” test and the “kink” test. The “kink test” might give a good impression of the effects occurring in case of maltreatment of the fibre or in case of “stapling” or “nailing” an indoor cable. In this test, a coated fibre is loosely pressed against a low radius pin over an angle of about 45 degrees. The fibre has some free space due to the distance of about 0.7 mm between the pin surface and the pressing surface resulting in a smaller effective bend angle as is the case in usual cable structures. The test is repeated several times and the results are averaged.

In Figure 6, some test results are shown applying a 1.5 and a 2 mm radius pin respectively. The tested fibres were nominal MAC value fibres from both ***BendBright***^{xs} and the classical BendBright product line. The improvement originating from the trench is impressive. In case of this severe maltreatment, ***BendBright***^{xs} fibre responds with a limited excess loss only. In case of a standard step-index SMF, the inserted loss would certainly have initiated a system alarm. Seen from this aspect, the new trench-assisted ***BendBright***^{xs} fibre is very installer friendly and forgiving. However, this does not mean that fibre mounting should be done carelessly.

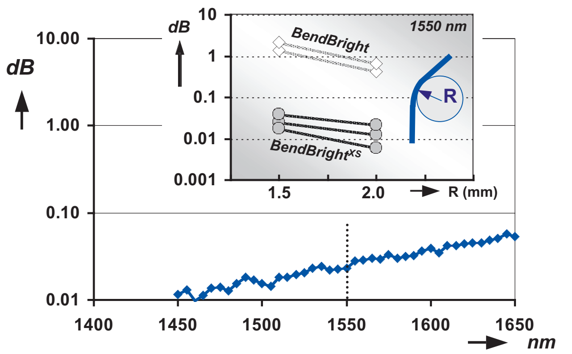


Fig. 6 Spectral “kink loss” curve for a ***BendBright***^{XS} fibre pressed against an R=1.5 mm pin. In the inset, the losses at 1550 nm are given for some nominal ***BendBright***^{XS} and BendBright fibres

5. Fibre connection

Fibre connection is of high relevance in installing, operating and maintaining an optical network. Not only for splicing consecutive or branched-out cable sections, but also in connecting cabled fibres to transceiver or splitter pigtails. The connection might be from connectors, mechanical splicing or fusion splices. The inter-compatibility of legacy fibre must always be considered when introducing a newer fibre type, even if improving its characteristics. Therefore, it makes sense to check the impact of the ***BendBright***^{xs} on each of these methods.

5.1: connectors

In cleaving, polishing and processing of the fibre end-face, ***BendBright***^{xs} does not differ from standard SMF. The surface of the trench is very small compared with the total fibre surface, so the small differences in material do not affect any of the processing steps significantly. This has been verified by making a series of connectors and testing the connection results in terms of insertion and reflection loss. No differences in characteristics resulted. As for the reflection loss it should be noted that one of the methods to suppress end face reflection i.e. by making one or more small radius loops in the fibre downstream the connector to be tested, does not work anymore. Alternative methods like the use of index matching oil or gels should be applied.

An interesting part of this test cycle was the tested patch-cord bend loss. In this procedure, a cord is bent over quite small radii at different angles as represented in Table I. The extremely low losses correspond fully with the results shown in Figure 3.

Table I: Results from bend loss tests at 1625 nm as part of a connector qualification program.

Angle	*Radius*	*ESMF*	*BendBright^{xs}*
1x180 °	9 mm	0.0 dB	0.0 dB
1x180 °	6.5 mm	0.2 dB	0.02 dB
1x180 °	4 mm	2.1 dB	0.2 dB
1x360 °	7 mm	12.5 dB	0.4 dB
1x360 °	5 mm	30 dB	1.0 dB
1x360 °	3 mm	38 dB	2.5 dB

5.2: mechanical splices

Just like the results for making connectors, the use of ***BendBright^{xs}*** does not differ from the use of standard SMF. As verification, a series of mechanical splices were been made, the result of which is represented in Table II. The average value and maximum value over 5 installations were both within the specifications for this type of mechanical splice.

Table II: Results from mechanical splice mounting trial series.

Wavelength	*Average loss*
1310 nm	0.09 dB
1550 nm	0.12 dB
1625 nm	0.12 dB
1250 – 1650 nm	0.12 dB

5.3: fusion splicing

In assessing the impact of ***BendBright^{xs}*** on the fusion splicing process, 3 different aspects have been evaluated, i) splicing in a network with ***BendBright^{xs}*** only, ii) splicing ***BendBright^{xs}*** to other G.652 SMF types and iii) the OTDR commissioning procedure.

*5.3-1: splicing **BendBright^{xs}** to **BendBright^{xs}***

Splicing ***BendBright^{xs}*** to itself works like splicing every other standard SMF in nowadays installation practice. Figure 7 shows an overall histogram of splice losses achieved with the modern splicing machines listed in Table III and applying the recommended splice procedures.

Mass-fusion splicing has been investigated in 12 fibre ribbons made with ***BendBright^{xs}*** fibres. These results complied with the general results obtained with standard SMF. Standard settings of the fusion machine (Ericsson RSU12) were applied.

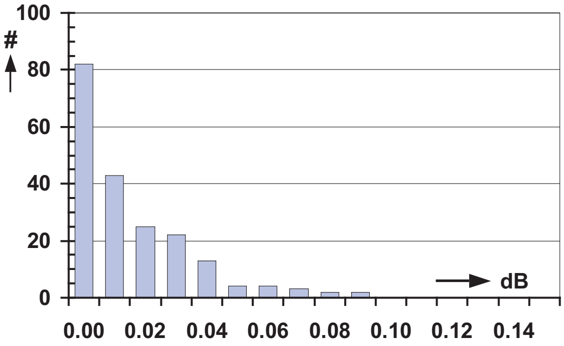


Fig. 7 Result of splicing a series of 200 ***BendBright^{XS}*** to ***BendBright^{XS}*** fibres applying the splicing machines listed in Table III.

*5.3-2: splicing **BendBright^{xs}** to ESMF*

Splicing the trench-assisted ***BendBright^{xs}*** fibre to a standard SMF will occur frequently at the edge of an access network or when splicing fibre pigtails in passive components like power splitters. Although the optical field confining trench represents a very small part of the total fibre cross-section only, it does influence the softening temperature of the fibre end slightly. This results in a-symmetric splicing for which not all fusion programs are suited[1]. A simple approach is to use the Multimode Fibre fusion program setting. This provides a lower temperature and a higher fusion time. Usually this program can be selected from the splicers program library. Figure 8 shows the overall results as obtained in this way with a conventional standard Fujikura FSM-30S machine.

---

[1] Some splice machine can optimize the arc position a-symmetrically between the fibre ends of dissimilar fibres. In such case repeat splicing should be performed with the same fibre type in the same splice holder orientation.

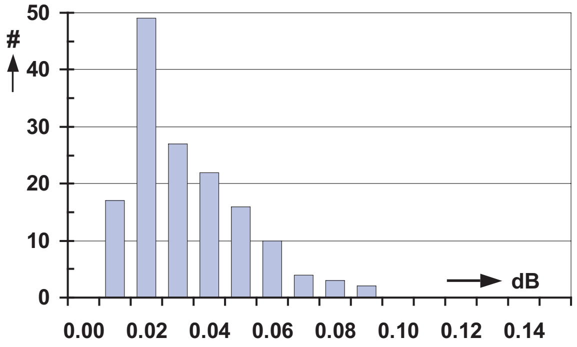


Fig. 8 Result of series of 150 splices ***BendBright***^{XS} to various standard ***SMF types*** on Fujikura FSM-30S applying the MMF fusion program

In a next refinement step, splicing machine manufacturers can optimize the settings in the fusion splicing machines. Please contact Draka Comteq or the local machine distributor for further details.

Although good results can be achieved with older splicing sets applying the MMF arc settings, Draka Comteq recommends applying modern splicers like the ones listed in Table III. If relevant, automatic fibre type recognition programs have to be switched off. The close vicinity of the core and the surrounding trench in ***BendBright***^{xs} requires too high resolution from the current recognition programs.

Table III: Recommended machines for fusion splicing of ***BendBright***^{xs}.

Fusion splice set	***Remarks***
Sumitomo T-39	Select the 'SMF Standard' program
Fitel/Furukawa S-122	Standard SMF settings
Fitel/Furukawa S-177	see note *)
Fujikura FSM 50 S	Auto-mode settings
Corning Optisplice	

*) *upgrade software for **BendBright**^{xs} available via distributor*

5.3-3: OTDR commissioning procedure

During installation, the splice loss is predicted by the optical image processing system of the splicer unit. Based on this prediction the splice can be approved or rejected. When commissioning an optical link, splice losses usually are checked again by OTDR testing from either one side or from two sides of the fibre link. For testing splices in networks with optical splitters special procedures do exist.

When measuring splice loss with an OTDR, peculiar effects can occur. Depending upon the direction of testing, apparent gain or apparent high losses can be observed. The reason for this is in the strong dependency of backscatter level on the MFD value. If the spliced fibres have different MFD values the backscatter level of both fibres will differ. This impacts the ability of the OTDR to measure the splice loss from one direction. More details are given in Refs [4] and [5].

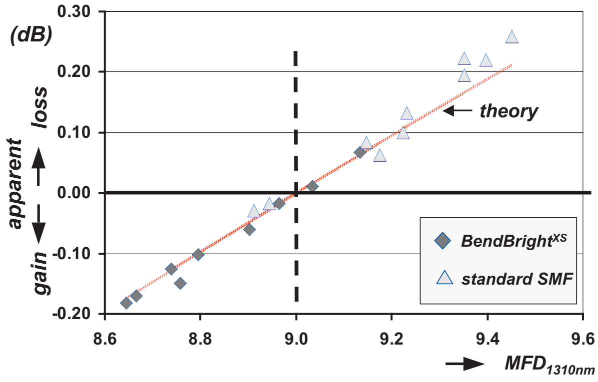


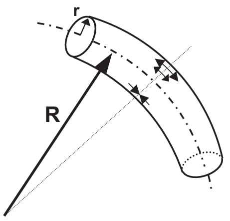
Fig. 9 Measured uni-directional OTDR gain or loss for an ideal splice at 1550 nm determined from a 9.0 µm MFD standard SMF launching into other standard SMF and into ***BendBright***^{XS} fibres with various MFD values indicated on the horizontal axis.

Also for ***BendBright***^{xs}, backscatter level is mainly determined by MFD. This is depicted in more detail in Figure 9. A standard SMF launch fibre with a 9.0 µm MFD is spliced to a series of other SMF with deviating MFD values. Applying the method used in Ref [6], the apparent loss (dB >0) or gain (dB <0), referred to the launch fibre can be derived for each fibre. Good correspondence shows with the expected theoretical value based on MFD differences (see Ref [4], Eq. 5), which is also represented in Figure 9. These results show that the trench-assisted ***BendBright***^{xs} behaves just like a standard SMF with respect to OTDR splice monitoring.

Since ***BendBright***^{xs} has a slightly lower nominal MFD then conventional SMF, more splices will be noticed with an apparent gain when testing from the side of the conventional SMF. In case of a commissioning procedure requiring the use of cost-effective single sided OTDR monitoring, this difference in average value of MFD distribution has to be taken into account. Methods to cope with this do not differ from situations where different standard SMF fibres with a difference in nominal MFD value are spliced (see also Ref. [4]).

5. Lifetime aspects

When deploying SMF in storage cassettes or in case of incidental bends, stress is applied to the outer circumference of the fibre causing strain in the glass material (see Figure 10).



strain:

$$\epsilon = r / R$$

Fig. 10 Strain in the outer surface of the fibre by bending the fibre axis with a radius R

Reducing the current minimum bend radius from 30 mm to 15 mm or even lower, might raise some questions on the lifetime of the fibre. For modern SMF however, there is no reason for this concern. With respect to strength, ***BendBright***^{xs} gets the same high quality processing as the Draka Comteq standard SMF. This is sufficient to guarantee its lifetime in all situations in a telecom network, including access networks with much more rugged environments. To explain this, let's start with an assessment of current strength requirements. These requirements have been derived from a worst case network situation defined as:

> **"all fibres in a cable observe over the entire length and during the entire lifetime of e.g. 20 years, a constant strain of maximum 1/3 of the 1% proof-test value"**

For modern optical fibres this requirement is met by applying high quality materials and clean processes. Verification is done by proof-testing the fibres resulting in a sufficiently low number of breaks per preform pull. Meeting this requirement for a 1% strain at proof-test, insures that the fibre can withstand a 1/3 % strain over its whole cross-section, length and lifetime.

When bending a fibre in a storage cassette the following main considerations apply:

1- Usually there is no axial stress on the fibre, so consequently the main cause for strain is the bending itself. By simple geometrical rules it can be calculated that a 1/3 % strain is reached at the outer circumference of a 125 µm OD fibre for a bend radius of 18.75 mm. Bending the fibre over its whole length on this diameter will not impose any additional impact on the lifetime compared with the criteria mentioned above. On the contrary, the average stress is even less as the 1/3 % strain is present in a very small part of the fiber's outer surface only.

2- The length of the bent fibre in a storage cassette is a very short section of the total fibre length only. So, the probability of failure is accordingly lower.

Both considerations apply when calculating the failure probability of a short fibre length stored in a cassette of a fibre management system. In Ref. [7] a more complete model has been described starting from the outside plant failure probability as indicated by the network operator. For a rather extended network containing 5000 storage cassettes and a failure probability per cassette of 0.001 % in 20 years, i.e. one single spontaneous breakage in one of the cassettes in 20 years in 20 of these networks, the minimum bend radius is represented in Figure 11.

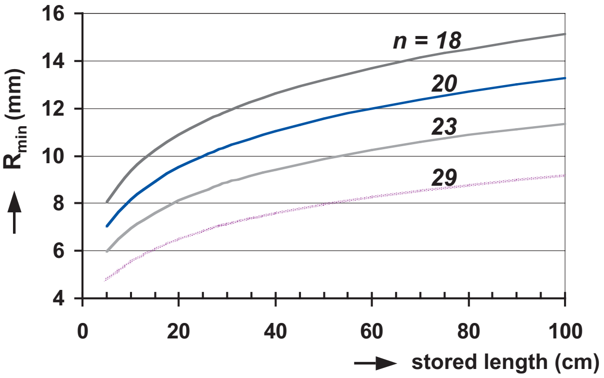


Fig. 11 Minimum bending radius for storage of the ***BendBright***^{XS} with a 20 years failure probability of < 0.001 %

It is evident that this minimum radius depends upon the length of the stored fibre in the cassette. The other parameter that governs the minimum bending radius is the stress corrosion susceptibility n (fatigue parameter). For ***BendBright***^{xs} the value of the "dynamic" susceptibility is >20 (see datasheet) whereas the "static" value is >23. Note that the minimum dynamic stress corrosion susceptibility coefficient is 18 according to IEC product specification 60793-2-50 and Telcordia GR-20-CORE specifications.

Depending upon the envisioned safety margin, different values can be used. Since storage aging in most cases is a static phenomenon, the use of the higher static fatigue parameter n=29 might be justified. The lower value of n=18 might be used as a "worst case". Dependent upon these considerations the curves in Figure 11 demonstrate that for this typical network and the accepted very low failure rate a storage length of, for example, 100 cm of fibre at a 15 mm radius is a safe situation. However, storage of 100 cm of fibre at a radius of 10 mm is also safe if the higher n-values are ascertained *).

The curves in Figure 11 also show that for much *lower bend lengths*, such as 90 degree bends in exit and entrance ports of a fibre management system the minimum radius can be much shorter. Referring to the kink loss situation as indicated in Figure 6, detailed calculations reveal that even in these cases, lifetime is not significantly affected (see e.g. Ref. [8]; Fig. 9). A nice illustration of this comes from a simple long term experiment started at Draka Denmark in the early nineties of the last century. A series of different diameter mandrels, diameters ranging from 2.8 to 4.2 mm, 10 of each and each mandrel with 30 windings were stored in a room temperature environment. In the D=2.8 mm and D=3.0 mm series mandrels 5 breaks occurred after 11 and 28 days, respectively. However, from the D≥ 3.4 mm mandrels no breaks were detected up till now, i.e. 16 years later!

In conclusion it can be stated that lifetime considerations on fibres stored in short bend radius fibre management systems differ significantly from lifetime considerations of cabled fibres. For storage in fibre management systems, a higher strain may be present on short lengths, whereas for cables a lower strain and a much longer length apply. As for lifetime prediction however, similar calculation models can be applied.

---

*) *Note that at this specific bend radius, the bend loss in "live" fibres cannot be neglected anymore. For a for 100 cm storage with a bend radius of 10 mm, the specified maximum bend loss becomes as high as 0.8 dB at 1550 nm.*

6. Miscellaneous

The improved macro-bending loss of ***BendBright***^{xs} can also have impact on other areas.

- fibre and cable cut-off measurement.

In the cut-off region of a SMF, optical power is propagated not only by the fundamental mode, but also by higher order modes. For a standard step-index SMF the two LP_{11} higher order modes are the dominant ones just below the cut-off wavelength. In the *bend reference method of IEC and ITU-T standardized cut-off wavelength test methods* power is split in equal parts over the three propagating modes. This results in a spectral curve "hump" with a top value of 10xlog(3) = 4.7 dB. The cut-off wavelength follows from the higher wavelength at 0.1 dB height of this hump.

For trench-assisted ***BendBright***^{xs}, the cut-off phenomena differ significantly from those for a conventional step-index core profile SMF. As the bend loss of the higher order modes is influenced by the trench also, the wavelength width of the cutoff region is broadened significantly leading to a much lower "hump" value when applying the bend reference method. In addition, due to interference undulation in the measured cut-off curve can occur resulting in a "dispersed hump" with a much lower maximum value, even far below the minimum height of 2 dB as required in the IEC standard for this test method. Applying the *multimode reference method* (see Ref. [9]) does not have this drawback and is recommended for this test, both for the fibre and for the cable cut-off wavelength.

- use of fibre identifiers

The enhanced bending performance of ***BendBright***^{xs} will diminish the signal received with fibre identifiers. This might cause a sensitivity problem dependent upon the type of use and the type of tap-off mechanism. To investigate this, several identifiers were tested:

- Tests with the Wilcom F 6225 identifier showed that working with ***BendBright***^{xs} is possible with normal identifier settings for both the 250 µm OD primary coated fibre and a 2 mm buffered patch-cord.
- Tests with done also with the EXFO LFD-250 "clip-on" detector and the LFD-300 FiberFinder. Both work well as clip-on device to a sensitivity level of about -30 dBm at 1550 nm. For providing the appropriate power level software modifications will be required.

- high power induced aging

In view of the foreseen up-grading of networks with distributed or lumped Raman amplifiers, much attention is given currently to the effect of the use of high power pump lasers at e.g. 1460 nm. An annoying side effect might be that loss of power at low radius bends can initiate an accelerated aging of the coating and in some cases eventually lead to fibre breakage or even start of fire in some older types of tightly coated fibre. It will be evident that the use of fibres with improved macrobending behavior, like trench-assisted ***BendBright***^{xs} are much less vulnerable to this effect. Tests at a power level up to 5.4 W at 1480 nm showed no sign of any visible coating damage at or near to an 8 mm diameter 2-point 180 degrees bend even after a continuous exposure for more then 10 days. This outperforms a standard SMF significantly.

- use of local injection and detection methods in fusion splicing

Due to the perfection of the fibre end image processing systems implemented in modern fusion splicers, the Local Injection and Detection (LID) method has lost much of its early attractiveness. However, in several types of fusion splicers this method is still applied. Care should be taken in applying this method on ***BendBright***^{xs}. As the transmission length between the injection and the detection points is rather small, the injected power might very well be propagated by the inside-trench area of the optical cladding. Although alignment on the trench most probably results in good splice losses, the execution of a test series of fusion splices is recommended before applying the LID system in full operation.

- ORL measurements

For optical return loss measurements (ORL), e.g. IEC 61300-3-6, methods are identified to avoid that the Fresnel reflection from the rear side of the fibre is measured together with the ORL power.

Quite often a mandrel is used at the back side, introducing enough bending loss for this reflected light. Because of the superior bend-insensitivity of the ***BendBright***^{xs} fibre the usual number of turns and/or mandrel diameter might not give enough reduction of the back reflected light and could lead to mis-interpretations of the ORL value. For determining the ORL of the ***BendBright***^{xs} fibre the number of turns should be increased and the mandrel diameter reduced. An alternative is to use index-matching gel usually offering ORL results down to 55 – 57 dB. Also an APC connector at the back side can be used.

References

[1] L.A. de Montmorillon, P. Matthijsse et al, “Next generation SMF with reduced bend sensitivity for FttH networks”; Proc. ECOC, paper Mo 3.3.2, Cannes, 2006

[2] L.Faustini and G. Martini, “ Bend Loss in Single Mode Fibers”, Journal of Lightwave Technology, Vol 15, No 4, April 1997; pp 671-679

[3] C.Unger and W.Stöcklein, “Investigation of the Microbending Sensitivity of fibers”, Journal of Lightwave Technology, Vol 12, No 4, April 1994; pp 591-596

[4] Draka Comteq Application Note: “SM OTDRs, Apparent Gain, Loss and other surprises”; August 2006.

[5] IEC 62316 TR Ed. 2.0: “Guidance for the interpretation of OTDR backscattering traces”

[6] P.Matthijsse and C.M. de Blok, “Field measurement of splice loss applying the backscattering method”, Electronics Letters, Vol. 15, No 24, pp 795-6, (1979)

[7] P.Matthijsse and W.Griffioen, “Matching Optical Fiber Lifetime and Bend-loss Limits for Optimized Local Loop Fiber Storage”, Optical Fiber Technology, Vol 11, pp 92-99, (2005)

[8] P.Matthijsse, L.A. de Montmorillon et al, “Bend-Optimized G.652 compatible Single Mode Fibers”, Proc. 54th IWCS Conference, pp 327-331, November 2005

[9] IEC 60793-1-44, Ed.1: Optical fibres – Part 1-44: Measurement methods and test procedures – Cut-off wavelength; 2002