Splicing of bend-insensitive fibres

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Abstract

During the past few years new single-mode fibres have been developed and presented to the market which exhibit lower bending loss than common single-mode fibres, so-called "bend-improved" or "bend-tolerant" fibres. Recently a new "bend-insensitive" fibre type has been developed, which reduces bending loss by more than an order of magnitude compared to bend-tolerant fibres while being backwards compatible with standard single-mode fibres. This has been achieved through nanoStructures™ technology, enabling fibre optic cable designs that bring optical cable installation on par with copper communication cables. Since these new fibres differ in structure from standard single-mode fibres, modifications in some fusion splicing processes become necessary. Investigations of suitable fusion processes and the results are presented.

Introduction

The recent emergence of single-mode fibres with improved bending performance for the access network has been driven by the penetration of optical cable inside the building. In order to route these cables efficiently and unobtrusively inside buildings, design efforts have focussed on smaller diameter, more flexible units that can be routed into and around corners and may be affixed directly to the wall by means of stapling. In addition, discreet storage of fibre in the building, either for patch-cords or for excess lengths of fibre connecting between locations, also demands that the fibre can be constrained in bend radii that were previously considered unnecessary or impossible because of the associated signal loss. Some examples of in-building deployment are presented in Fig. 1.

The most interesting example for fibre-to-the-home (FTTH) installations is a fibre that incorporates nanoStructures technology in the cladding to tightly trap the light in the core and thereby deliver outstandingly low loss in the tightest bend configurations. The introduction of this innovative technology was preceded by investigations to demonstrate operability with commonly encountered installation equipment. It is very important to determine that the fibre can be spliced satisfactorily using fusion splicing equipment commonly employed in the industry.

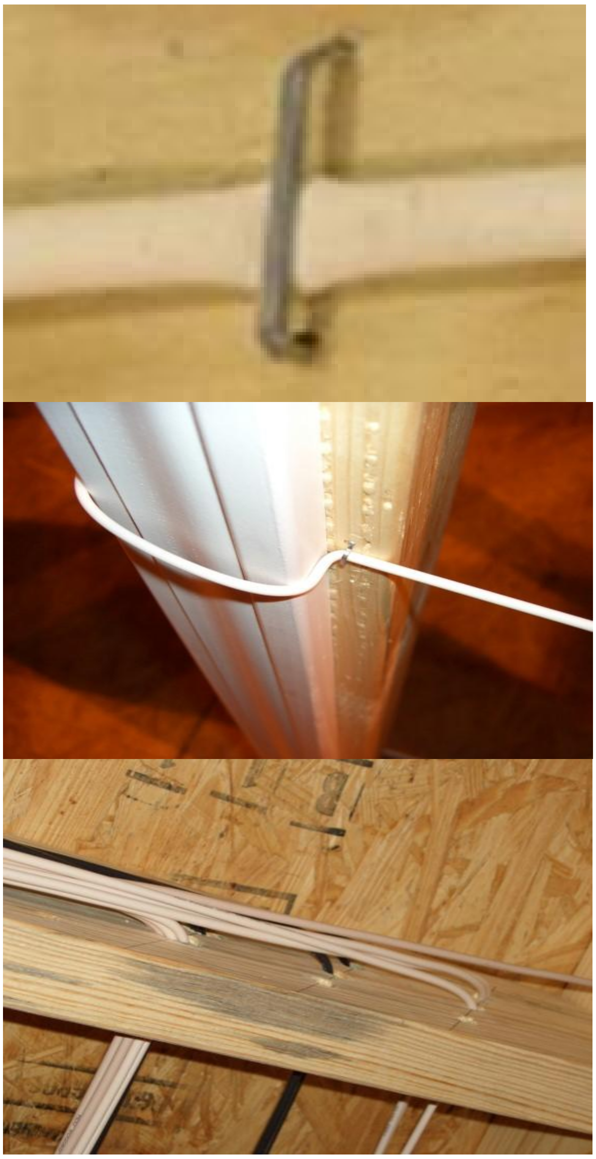

Fig. 1: Examples of in-building cable installations; stapling and cornering

Bend-insensitive fibres

The ITU Recommendation G.657 was published in late 2006 to support a range of new optical fibre products that experience lower optical loss than standard single-mode fibre types when configured in tight bends. This publication was drafted to address the challenges identified by operators attempting to install FTTH whereby drop-cable routing and fibre storage hardware imposed much tighter bend radii on the fibre than previously considered necessary. Two classes of fibre are identified in G.657. Category A is for bend-improved fibre for which enhanced macrobending requirements to 10mm radius are defined with the additional requirement for backwards compatibility with the installed network ensured by compliance to ITU Recommendation G.652.D. Category B is for bend-tolerant fibre for which further enhanced macrobending requirements to 7.5mm radius is defined but backwards compatibility through compliance to G.552.D is not required. This category includes such speciality fibres as hole-assisted fibres (HAF) and photonic crystal fibres (PCF) which, in addition to their non-compliance to G.652.D, tend to be significantly more complex to manufacture in volume than conventional fibre types and present compatibility issues with the installed base.

Considering the preferred installation techniques within buildings that operators have identified for FTTH installations, routing into and around corners and affixing directly to the wall by means of stapling, it is evident that a need for macrobending capability beyond G.657 Category B exists, i. e. a truly bend-insensitive fibre that can meet the challenge of deployment to bend radii as low as 5mm. An order of magnitude improvement in bend loss at 5mm with a fibre that is still compliant to ITU Recommendation G.652.D has been achieved by incorporating nanoStructures features into the cladding of the fibre. In practical, in-building deployments, this improvement can make the difference between exceeding the network power budget and installing a fully operable link to the subscriber. The manufacturing requirements for this fibre are consistent with the equipment used for conventional, mass-produced single-mode optical fibre, therefore this fibre is suitable for manufacture in established, high volume operations. Thus, nanoStructures technology effectively breaks the industry convention that improved macrobend performance of single-mode fibre can only be achieved by sacrificing compatibility with the installed network.

Splicing of bend-insensitive fibres

Splice studies with the new, bend-insensitive nanoStructure™ fibre show that common fusion splicing is well suited for connecting this new fibre type. This is true for splicing fibres with nanoStructures technology to fibres with nanoStructures technology as well as fibers with nanoStructures technology to G.652.D fibres like SMF28e® fibre. Some fusion splicing techniques, however, require setting adjustments to accommodate the presence of the nanoStructures features.

Two widely used core detection methods, for example work with only slight modifications as is shown in the following sections.

Core detection via profile analysis

Core detection in fusion splicers with high magnification optics is usually performed by analyzing slight variations in the intensity profile of transmitted light. Since the nanoStructures technology leads to significant intensity variations around the core region, the core is not directly visible.

Core detection is still possible with such kind of fusion splicers by modification of the fusion splice programme. This can be achieved, for example, by using an extended cleaning arc time as a preparational step. A feature of this method is a rounding of the fibre ends which can lead to slightly increased splice loss.

Hot core detection

A core detection method that is equally well suited for standard single-mode fibres as well as bend-insensitive fibres is the “hot core detection” method utilizing thermally induced intrinsic luminance. This procedure makes use of the fact that with increased heat, optical fibres emit radiation within the visible spectrum of wavelengths – thus detectable with silicon based CCD cameras [1].

Due to the different doping of core and cladding and the resulting different optical characteristics, their emittance is of varying intensity [1]. Thus with the germanium doping used in standard single-mode fibres as well as bend-insensitive fibres, the core glows brighter than the cladding; consequently the core position can be determined by laterally inspecting the fibre. For this, pictures of the luminous fibre are taken after a short period of electric arc ignition. A picture of two luminous fibre ends is exemplified in Fig. 2, where the fibre core emerges clearly visible.

The longer the electric arc is burning, the better the fibre core is visible. A profile of the intensity distribution perpendicular to the longitudinal fibre axis is exemplified in Fig. 3.

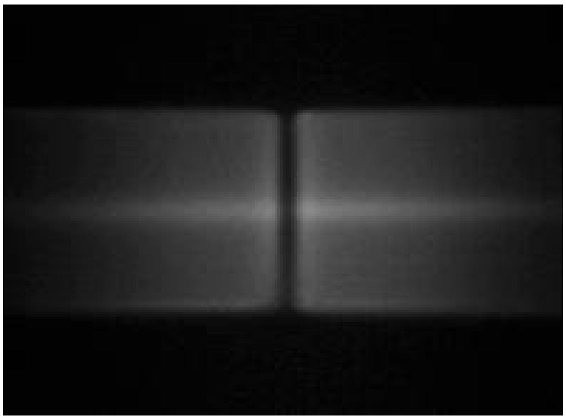

Fig. 2: Picture of two heated nanoStructures™ fibre ends

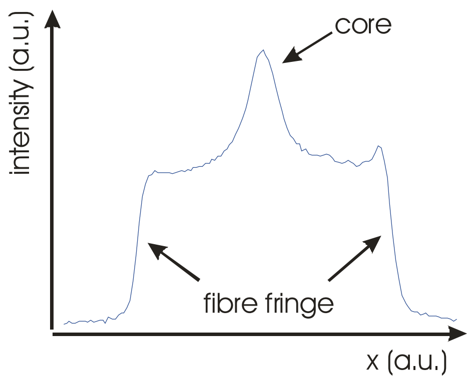

Fig. 3: Profile of the intensity distribution of a luminous nanoStructure fibre

Tests have shown that with a usual current intensity of 14.5mA of the electric arc, a time of 350ms is sufficient to determine the core position with an accuracy of better than 0.05µm. As can be seen in Fig. 4, visibility of the core of a nanoStructures fibre is as good as for standard single-mode fibre, and virtually no impact of nanoStructures fibre on core detection is observed.

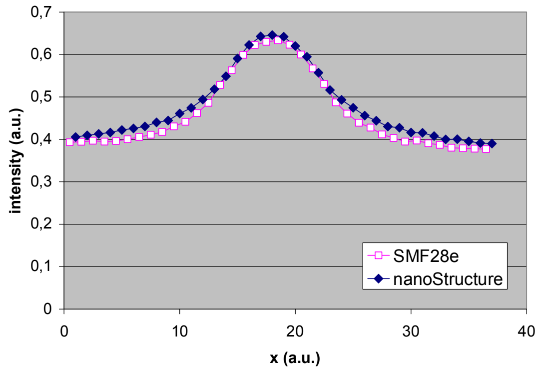

Fig. 4: Comparison of intensity profiles of the fibre core between SMF-28e® and nanoStructure fibres

Splice Quality

Splices with nanoStructures fibre were performed with different fusion splicers, utilizing different fibre positioning methods. Besides the hot core detection discussed above also fixed-V-groove alignment and cladding alignment have been examined. It turns out that the new bend-insensitive fibre can be spliced by using splicing parameters only slightly adjusted from those used for standard single-mode fibres. Additionally, splice loss as well as splice strength is comparable to that of standard single-mode fibres.

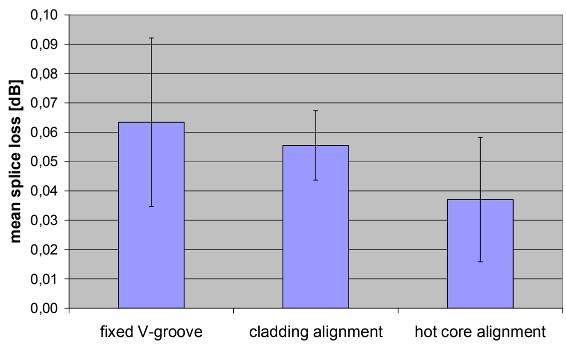

Fig. 5: Measured mean splice loss at 1310nm for nanoStructure fibres spliced in different splice modes; error bars indicate standard deviation

Fig. 5 shows a comparison of mean measured splice loss for different fibre positioning methods. For splices with fixed-V-groove alignment, a fusion splicer of type “OptiSplice™ one” from Corning was used with a splice program optimized for bend-insensitive fibres. The resulting average splice loss of 0.06dB is comparable to that of standard SMF-28e fibres, which is of the order of 0.04dB.

Slightly reduced splice loss can be achieved if the fibres are spliced in cladding alignment mode. The results of splice tests with a Corning “OptiSplice™ LID” fusion splicer, operated in “VIDEO” mode (i.e. cladding alignment mode) show an average splice loss of 0.055dB.

Splice loss could be reduced even further by splicing in core alignment mode. For the corresponding splice tests, a Corning “OptiSplice™ LID” fusion splicer was used with “hot core detection” (CDS mode). For an optimum splice time of 3.0s an average splice loss of 0.04dB was achieved. This was only slightly higher than the average splice loss of 0.02dB that is achieved for SMF-28e® fibre.

Slightly elevated splice loss compared to conventional single-mode fibre will not be a functional issue in the context of the overall power budget of an FTTH installation. Best practice is to minimise the use of splices, so that an additional 0.02dB splice loss will be negligible in relation to the 17- 20dB of loss contributed by the splitters or the 3-5dB of loss originating from the attenuation of cabled optical fibre. The impact on overall power budget is also more than compensated by the order of magnitude improvement in loss achieved in bending of nanoStructures fibre to 5mm radius in practical deployments. Further improvement in splicing of nanoStructures fibre will be achieved as experience with the product increases.

Summary

A new single-mode fibre has been developed, which is not only truly bend-insensitive down to bend radii of 5mm, but also backwards compliant to standard single-mode fibres. The improved properties have been achieved by incorporating nanoStructures features into the cladding. Tests show that fusion splicing properties are comparable to that of standard single-mode fibres with only slight modifications to fibre alignment processes.

References

[1] T. Katagiri, M. Tachikura, K. Ishihara: “Direct core observation method using thermal radiation of silica fibers with dopants”, *Electron. Comm. Japan, Part 2 (Electronics) 71 (1988), no. 11*, pp. 77-85

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