200-Micron Single-Mode Fiber Enables New Cable Designs

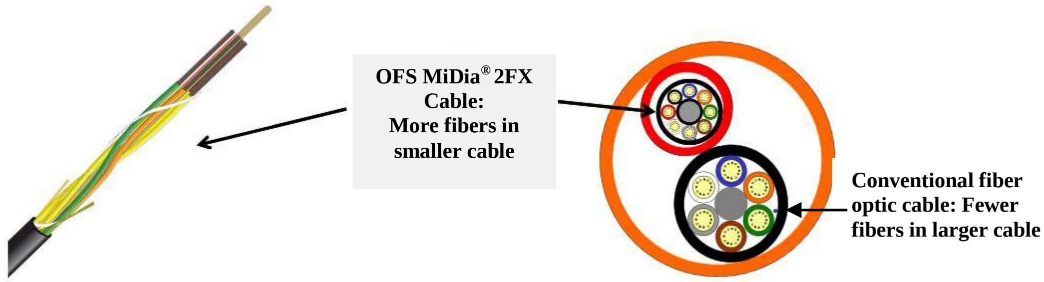
Since single-mode optical fiber was first introduced in the early 1980's, little has changed in its basicgeometric parameters. The core size has remained between 8-10 microns, the cladding of the glass has remained at 125 microns, and the coating is still 250 microns. Standardizing these dimensions has greatly improved interoperability and consistency across the optical network. Recently a new generation of single-mode fibers with a smaller 200-micron coating dimension has become available. This new dimension has enabled novel, compact cable designs that give telecom providers new options for their optical networks.

The case for crowded ducts

There are two trends that have become apparent in the deployment of modern high-performance networks. One is the need for low-count fiber optic cables to connect single subscribers or buildings; the second is the need for very high-count cables to distribute large volumes of information. As the average fiber count in the second group continues to increase, some fiber optic cables now feature well over 500 optical fibers in a single cable.

In most cases, scaling up the fiber optic cable design using current practices is the preferred approach. However, this option is sometimes not available due to limited duct space. Most often, ducts are deployed in advance of the cable and the dimensions are fixed. In these situations, a network operator has two choices: (1) limit the number of fibers deployed for the given link , or (2) deploy a new cable design with smaller dimensions than what has been typically used.

In addition, microcables can offer an economic advantage when existing ducts are subdivided within smaller microducts. This method can be used to help avoid the expense of civil works and approval processes with local authorities.



The figure above illustrates how microcables have evolved to feature twice the fiber density that was offered a few years ago. While both cables have 288 fibers, the conventional cable is 14 mm in diameter, while the newer design is 9.6mm. The new design takes advantage of the new 200-micron coated fiber and is 36 percent smaller than the traditional cable.

The evolution of microcables has been enabled by both new design approaches and materials. Key design modifications include:

- Placing fibers in smaller tubes
- Designing cables to be blown into the duct rather than pulled

New ITU-T G.657 fibers and new optical fiber coatings have allowed for tighter packing densities. Even with the space minimized between the fibers in these compact designs, the fiber optic cables can meet industry-recommended crush requirements as well as low temperature performance requirements. Because the air-blown method is now the preferred cable deployment technology in Europe, fewer strength members need to be incorporated into thecable design. Together these new constraints have enabled the latest generation of smaller microcables.

The net result is a significant improvement in the fiber density of fiber optic cables. A few years ago, a cable diameter of over 10 mm was required for a 48-fiber cable design. Today, we can place 288 fibers in a cable that is less than 10 mm in size. This change clearly illustrates the great progress that has been made in this area. The advent of 200-micron coated fibers has made these achievements possible (see the figure above).

In summary, as we reduce the size of the cable elements, a larger percentage of what remains in the cable is optical fiber. The cross-sectional area of the 200-micron coated fiber is 36% smaller than that of the 250-micron coated fiber. Thus, with no other modifications to the design, we can expect to reduce the cable dimensions by simply by reducing the fiber coating thickness. That said, the new product must be both useable and reliable for the end product to have any value.

Using 200-Micron Optical Fiber

In the current issue of the ISO/IEC 60793-2-50 single-mode fiber specification, 200-micron coated fiber was included as an alternate coating dimension. The IEC optical fiber and cable working groups reviewed practical as well as reliability data from several industry experts. They concluded that 200 microns is a reasonable dimension for coated single-mode transmission fiber and should be included in the new standard. In addition, Telcordia GR 20 (to be published soon) also makes reference to this alternate coating dimension. With this fiber now standardized, a growing number of service providers are seeing value in this product and are considering it for use in their networks.

The 200-micron coated fiber works well in the field using current tools and practices. Conventional stripping tools effectively remove the acrylate coating. Once the coating is removed, the bare fiber has the same 125-micron dimension (diameter) as 250-micron coated fiber. Therefore, cleaving and fusion splicing can be accomplished with the same tools as conventional fiber. Our internal splice studies show no difference between splicing similar and dissimilar fibers. The average splice loss for various combinations of OFS' AllWave® *FLEX* Optical Fiber using a FITEL® S177 or S178 fusion splicer are shown in the table below:

	200-micron coated AllWave *FLEX* Fiber	250-micron coated AllWave *FLEX* Fiber
200-micron coated AllWave *FLEX* Fiber	0.03 dB	0.03 dB
250-micron coated AllWave *FLEX* fiber		0.03 dB
NOTE: Each square represents the average loss of at least 250 splices		

Table: Average Splice Loss for Various Optical Fiber Combinations

With single fiber connectors, the 200-micron coated fibers are up-jacketed before the connector is attached. Once again, the alternate coating dimension has little or no impact on single fiber connectors.

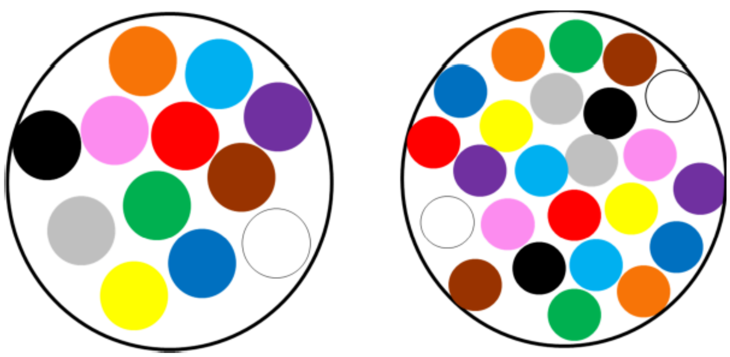
A key performance difference does occur when 200-micron coated fibers are used in ribbon structures and with MPO connectors. In both these cases, the coating impacts the spacing of the optical fibers and how they are joined in either the mass fusion splice apparatus or the MPO connector.

The 200-micron optical fibers are not recommended for use in multi-fiber junctions since there is currently no generally-accepted solution for their use.

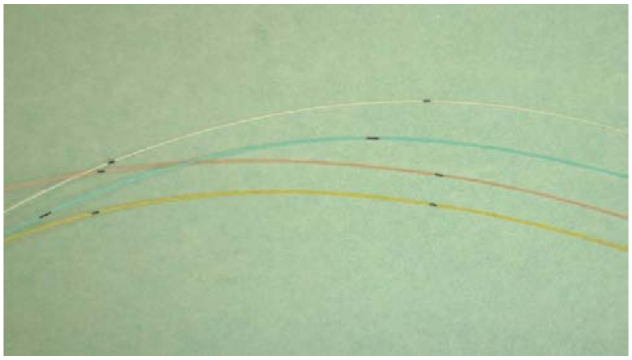
We have used 200-micron coated fiber in several field deployments as well as in the laboratory. Our practical experiments have shown no issues with deploying these fibers in the field using current procedures and practices. If a repair is needed, the alternate coating diameter will not impact the technician's ability to restore the optical link.

Marking fibers

One practice that can help to further reduce cable dimensions is to place more fibers in a given buffer tube. For example, the figure below illustrates that 24 200-micron optical fibers occupy approximately the same amount of space as 12 conventional fibers. In fact, while the packing density is slightly higher using 200-micron coated fibers, microbending effects can be minimized by using a G.657 fiber with a microbend-resistant coating. Using this scheme, the fiber count for a given cable design can be doubled.



One challenge remaining with this approach is that the use of more than 18 fiber colors makes it difficult to distinguish fibers based on color alone. For this reason, a new approach is required for fiber identification. One option is marking fibers. One key requirement for this method is that the marks must be visible both initially and also after aging, and that the marks must not disappear during standard processing. The picture below shows examples of ring-marked fibers.



Improvements in reliability

Long-term reliability is a key concern with optical networks. When building an optical network, the actual cost of cable and passive components represents a relatively small amount of the overall investment (typically less than 20%). The cost of the fiber optic cable installation is much more significant and greatly impacts the overall deployment budget. The payback on this investment often takes more than 10 years. In order to make the investment worthwhile, the deployed optical fiber must operate properly for the expected lifetime of the network, thereby supporting possible future network upgrades.

Reliability is the measure of how well the fiber optic cable stands the test of time. There are two types ofreliability that impact fiber optic networks: optical reliability and mechanical reliability.

Optical reliability requires that there is a useable optical signal after the system is deployed and that performance will be maintained for the life of the network. Tests such as the long-term aging of fiber optic cables, crush tests and temperature cycling are used to evaluate long-term optical performance. OFS is a leader in providing reliable optical links with several innovations that help to preserve optical reliability:

- AllWave® Zero Water Peak Fiber helps to ensure that attenuation is both low and stable
- AllWave® *FLEX* ZWP and *FLEX+* ZWP Fibers provide excellent microbend and macrobend performance to help ensure that temperature changes and cable movement do notimpact system performance
- OFS' D-LUX® Ultra Coating provides excellent durability and microbendperformance
- The AllWave optical fiber family provides excellent PMD properties that help ensure that the optical fiber is ready for both current transmission strategies and for next-generation systems as well.

The second type of reliability is mechanical reliability. This reliability measures whether the optical fibers will physically break. Optical fibers are very strong, with an intrinsic strength greater than 500 kpsi, but may have flaws that are distributed throughout its length. Methods for estimating the long-term mechanical performance for optical fiber are well documented in ISO/IEC TR 62048 Power Law Reliability. Key parameters to be preserved are proof test strength, dynamic fatigue coefficient (n-value) and the tensile strength of the fiber both initially as well as after the aging of samples. Once again, while optical fiber is strong, the fiber surface can easily be damaged by the environment. Therefore, the coating layer and how it adheres to the fiber helps ensure the mechanical integrity of the fiber.

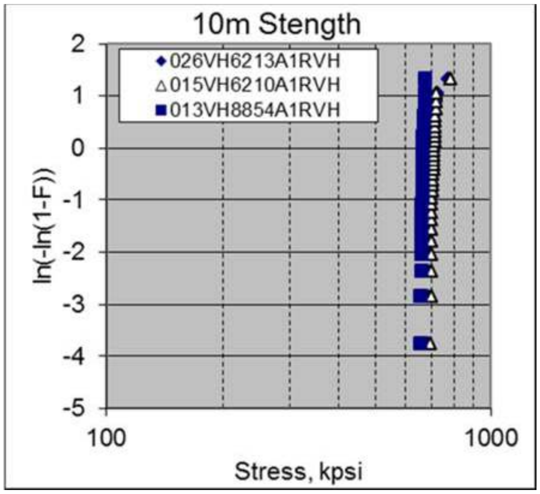
Optical fibers with 125-micron glass and a 250-micron coating have been deployed for over 30 years. Time has shown that the 62.5 micron acrylate coating layer is sufficient to preserve the fiber for more than 30 years. These 200-micron coatings have provided similar performance and are being deployed by several service providers.

Reliability of 200-Micron Fiber Coating

Since optical fibers were first deployed more than 30 years ago, there have been considerable advancementsin fiber quality. The quartz used to fabricate the bulk of the fiber, which was originally natural material, is now high-quality synthetic material. There have also been improvements in the quality of polymers which help to provide a significantly better product today. In fact, many optical fibers deployed in the 1980s are still operating today.

With these improvements in materials, our reliability tests indicate that OFS 200-micron coatedfiber is also capable of surviving 30 years in the field. OFS has tested and demonstrated that our 200-micron coated AllWave *FLEX* and AllWave *FLEX*+ Fibers comply with the full set of fiber tests in section 4 of Telcordia GR 20.

For example, the fiber tensile strength of both aged and unaged fiber is consistently well above 600 kpsi. The result of 10-meter gauged length axial strength tests may be even more revealing. The figure below clearly shows that OFS 200-micron coated fiber demonstrates high strength results when tested under stringent conditions.



When tested for dynamic fatigue using the more stringent axial strain method, the 200-micron coated fibers consistently yield results of n_d>20 for both unaged and aged samples.

Summary

Single-mode optical fiber is now available with an alternate 200-micron coating dimension. This smaller coating dimension is compatible with the embedded base of optical fibers and provides 36% smaller fibers that can be used to reduce the diameter of microcables. These fibers offer a new and reliable solution to address the challenge of deploying high-fiber-count optical cables in crowded duct spaces.

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