Single-Mode Fiber

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ColorLock-XS

Draka Fiber Coating

Application Note

VALUE INNOVATION

Draka

1. Introduction

Draka has a long history in fiber production from which it developed technical leadership in optical fiber coatings.

From one perspective, the new ***ColorLock-XS*** coating is the result of many years of hard work; from another perspective, one might argue this is a natural match.

DLPC 9, low modulus, soft primary

Draka, the world's largest multimode fiber supplier was the pioneer in developing a low modulus, low micro-bending sensitive multimode coating (DLPC 7, later DLPC 9). DLPC 9, features a low modulus primary, resulting in excellent strip-ability (no coating residue) and low micro-bending sensitivity. This makes DLPC 9 the preferred coating in tight buffer cable designs and ribbons, allowing the cable designers to move forward to more aggressive, cheaper cable designs.

ColorLock, integrated colors

The introduction of ColorLock in 1994 surprised the world. This coating with an integrated color in the outer primary coating layer not only eliminates a process step in the manufacturing process of optical fibers, but it also improves the lifetime guarantee and reduces the diameter of colored fibers.

Universal natural coating, DLPC 9

With the introduction of new ***ColorLock-XS*** Draka Communications is able to offer it's customers a universal natural coating: DLPC 9, an industry leading universal solution for both single-mode and multimode fibers. Starting April 2008, all fibers from Draka Communications ordered with natural coating are delivered with DLPC 9, which is fully compatible with new ***ColorLock-XS***.

New ColorLock-XS, combining the best of two worlds

Traditional photo-initiators for low modulus coatings required high doses of UV-light to get a proper coating cure rate on the fiber, which was in conflict with the UV absorbing pigments in the ***ColorLock-XS*** secondary.

The development of new photo-initiators made it possible to combine the best of two worlds. Draka Communications was able to develop a coating which combines the low modulus primary with the integrated colors in the secondary, while improving the brightness of the colors.

The ***ColorLock-XS*** fiber coating system consists of two layers of specially engineered acrylate coatings, see Figure 1. The inner primary coating layer next to the fiber is made of a low modulus material, which provides a soft cushion to protect the surface of the fiber from any micro-bending forces. The outer primary layer, made up of a higher modulus material, provides tough outer protection. This allows the fiber to be flexible while contributing both mechanical and environmental protection.

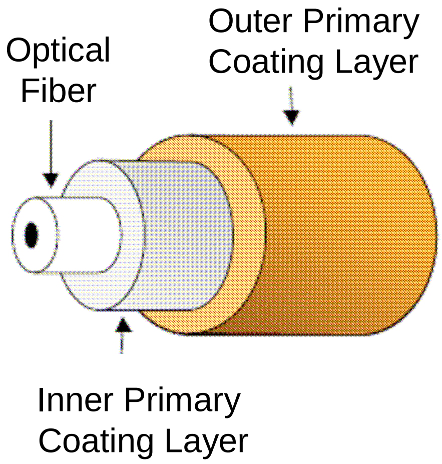

Fig. 1 Schematic drawing of Single-Mode Fiber

The Dual Layer Primary Coating of Draka's ***ColorLock-XS*** system, applied during fiber drawing, bonds immediately to the pristine glass and creates a barrier against any outside contaminants or effects of harsh environments. The coating system protects the glass surface from moisture and other environmental effects, which can impact the fiber's strength and long-term reliability.

With the ***ColorLock-XS*** coating system, the fiber user has the greatest assurance of long-term strength, performance and reliability.

2. Advantages

The chain of ***ColorLock-XS*** benefits are:

Fiber: easy handling

Draka has realized that applications for people should combine a high level of optical transmission characteristics with user friendliness for installation and maintenance.
This new coating gives a strong protection to the fiber. While the inner coating is soft and flexible, the outer layer is firm. The color coated optical fiber distinguishes itself in its stability in severe endurance tests. The results stand out so well, Draka is able to offer a product that can endure severe environments for 30 years and more.

Cable: compact and robust design

Reduced cable diameters are obtained with decreased diameter colored fibers and allow for smaller drums and spools plus in addition savings in transport and storage. These advantages can be taken to the next level with the forgiving character of the ***ColorLock-XS*** coating. The extremely aggressive Ribbon 60℃ 30 days watersoak test proves the coating has a high delamination resistance which makes the fiber suitable for more aggressive cable design like ribbons and tight-buffer cables. The 242 µm colored fiber diameter allows the cable designer to propose even smaller assemblies.

Installation: ultimate solution for mass installation

The vibrant colors of the ***ColorLock-XS*** coating make color recognition in dark manholes and in gel filled cables easy and fast. Keeping the flashlight out, keeps the speed up. On top of this, ***ColorLock-XS*** features excellent strip-ability and comfortable handling, an important advantage for splicing and connecting. Draka's access solution can be viewed as the ultimate solution – in time and money - for mass installation.

Ownership: minimizing operation costs

If you examine the total cost of ownership for network operators, all access line benefits come together. The high n value (see paragraph 3a) guarantees a long lifetime. Unlike off-line ink colored fiber, the integrated color in the outer primary coating layer extends this guarantee to colored fiber:
1) the fiber is screen-tested once colored;
2) the colors remain vibrant and do not vanish throughout the lifetime of the fiber.
The robust character and bright colors of the product reduce cost of installation, maintenance and the amount of rework.
Draka's access line is able to minimize the operation costs while still offering a high endurance network.

3.a. Testing: Environmental and strength performance

60℃ 12 fiber ribbon water soak test

The most severe test for optical fibers one can think of is probably the 60℃ 12 fiber ribbon watersoak test. Usually, f ibers in the ribbon show an irreversible increase in attenuation after a certain time. This increase is due to delamination of the primary coating. The high water temperature of 60℃ accelerates possible delamination.

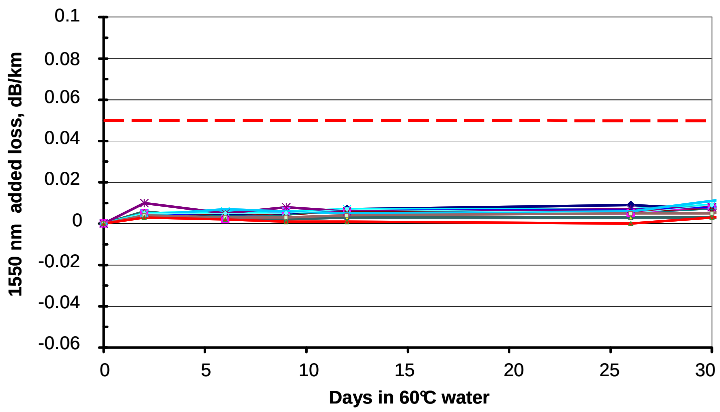

Fig. 2 Ribbon (12 fiber) watersoak test

A ribbon is considered to pass the test if no significant attenuation increase is observed in the first 30 days. The figure 2 shows the attenuation change during 60℃ watersoak of a twelv e (!!) fiber ribbon made with G.652.D fibers with the new ***ColorLock-XS*** coating demonstrating its extremely well behavior.

Filling gel soak test

When cabled most fibers will be immersed in filling gel for decades. This gel is designed to protect the fiber from its surroundings and give it freedom to move inside the cable. To ensure compatibility between fiber coating and gel, 7 different gel types were selected for testing that represent the majority of available cable gels. Fiber samples of all colors were immersed in these gels for 90 days at 10℃ and 60℃. The influence of the gels on the fib er coating was measured by determining the strip force. All measured values fulfill the specification requirements indicating that there is very little influence of the gel on the strip force and that the bond between glass and coating is not impaired.

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Ageing

Like the other Draka coatings ***ColorLock-XS*** easily passes all IEC temperature cycle test, see type test report for details. Table I shows a summary of the test results.

Table I: Ageing test results

	Induced attenuation	
Test conditions	**Typical value (dB/km)**	**IEC 60793 (dB/km)**
IEC 60793-1-50 (85℃/85% RH 30 days)	≤ 0.005 dB/km	≤ 0.05 dB/km
IEC 60793-1-51 (85℃ Dry Heat 30 days)	≤ 0.005 dB/km	≤ 0.05 dB/km
IEC 60793-1-53 (Water Immersion 30 days)	≤ 0.005 dB/km	≤ 0.05 dB/km

Dynamic fatigue and strength

ColorLock-XS distinguishes itself from other coating in its stability of the dynamic fatigue tests after ageing. Fiber strength before and after ageing is researched by dynamic two-point bending. The dynamic stress corrosion susceptibility factor (n_d) can be calculated from the dynamic two point bending results. A higher n_d value means a higher resistance to fatigue.

The table II and III show dynamic two point bending results for ***ColorLock-XS***, before and after stress free ageing in water of 60℃ and humid air of 85℃/85% RH. Results are in compli ance to, and exceed IEC 60793-2-50: n_d > 18 and Median strength > 3.8 GPa, and Telcordia GR20: Median strength > 3.8 GPa.

Table II: Stress corrosion susceptibility test results

Condition	**Mean n_d**
As drawn	27.7
30 days aging at 85℃ / 85% RH	24.0
30 days dry aging at 85℃	29.1

Table III: Strength test results

Condition	**Median tensile strength**	**15 percentile tensile strength**
As drawn	4.69 GPa (680 kpsi)	4.00 GPa (580 kpsi)
30 days 85℃/85% RH	4.48 GPa (650 kpsi)	3.51 GPa (510 kpsi)
30 days aging at 85℃ dry air	4.20 GPa (610 kpsi)	3.58 GPa (520 kpsi)

3.b. Testing: Micro-bending and low temperature performance

In order to establish a relative comparison of micro-bend sensitivity between the typical commercial primary coated fiber and fiber with ***ColorLock-XS***, two different methods were used for an evaluation. Both methods are designed to provide aggravated lateral stress conditions (where the second method actually goes well beyond what is normally encountered in the field). After measuring the effect on attenuation at room temperature, the test structures can be temperature cycled to determine the additional loss induced by the temperature excursions.

The first test is a basketweave/temperature cycling procedure. The sample fiber is wound at 50 grams tension on a 300mm diameter quartz cylinder with a 9mm “lay”. This creates numerous crossovers fiber-to-fiber in the course of winding 50 layers on the drum. The crossovers can cause added loss at room temperature if the fiber is sensitive enough, but normally little or no added loss is seen at this point. The drum with fiber on it is temperature cycled, in this experiment through -40℃/-60℃/+70℃/23℃ two times while making loss measurements at 1550 nm after one hour at temperature through the cycles.

Figure 3 shows typical results for samples of the new coating system versus samples of a typical commercial system. Both coating systems utilize colored outer primary layers, but of different formulations.

The fiber specimens were chosen to match coating geometry, mode field diameter, and cut-off wavelength.

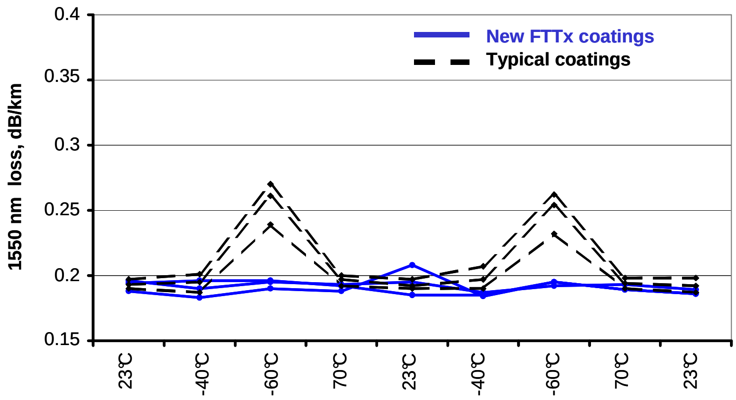

Fig.3 Basketweave/temperature cycle results for typical commercial SM coating system (dashed) and the optimized coating system (solid).

The two different coating systems both give good protection against the micro-bending stresses at 23℃. At -40℃ the typical commercial primary is close to its T_g but still provides good protection against micro-bending by stress relaxing in a reasonable timeframe. Only a small added loss is seen at -40℃ in the typical primary and none in the optimized primary fiber. At -60℃, the optimized primary is likewise close to its T_g, with similar protection still provided, but the typical primary is now well below T_g and the fibers show added loss.

Desiring a more aggressive micro-bending environment, for the second method we modified the IEC sandpaper drum test [7] to provide a harsh micro-bending stress situation strong enough to affect single-mode fiber even at room temperature. To do this, a 300 mm diameter quartz drum was wrapped with adhesive backed, 40 grit sandpaper, creating a very rough surface around which a single layer of fiber was wound at 100 grams tension. Using matched fiber samples as with the basketweave/temperature cycling test, the 23℃ attenuation was measured after winding. Then the drums were cycled to temperature extremes, this time measuring attenuation at 1550 nm after one hour and again after four hours at temperature. The results are given in Figure 4.

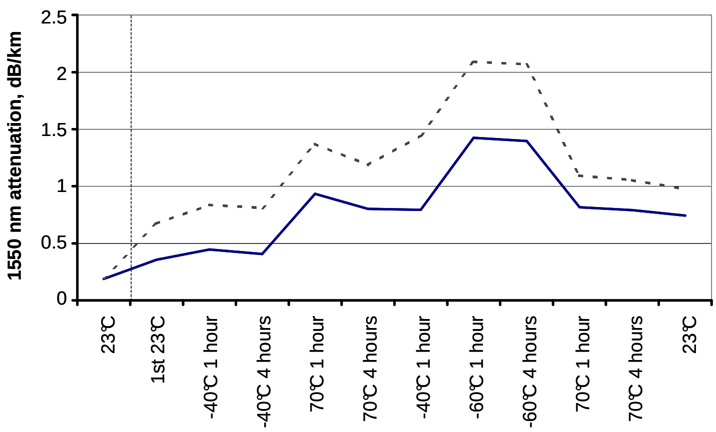

Fig.4 Sandpaper drum/temperature cycle results for typical commercial SM coating system (dashed) and ***ColorLock-XS*** (solid).

The initial measurement at 23℃ taken while the fiber was on the original spools shows similar loss of about 0.19 dB/km for these fiber specimens. After winding the drums, still at room temperature, the lower modulus of the optimized primary layer offers significantly better protection than the typical primary layer, with 1/3rd the added loss.

Throughout the very demanding range of temperature and rough drum conditions, the fiber with the optimized coating shows much lower micro-bending response than a typical commercial fiber with standard coating.

One of the benefits of low sensitivity to micro-bending is the reduced influence of extreme temperatures on the fiber. The Figure 5 shows that extremely low temperatures (- 60℃).

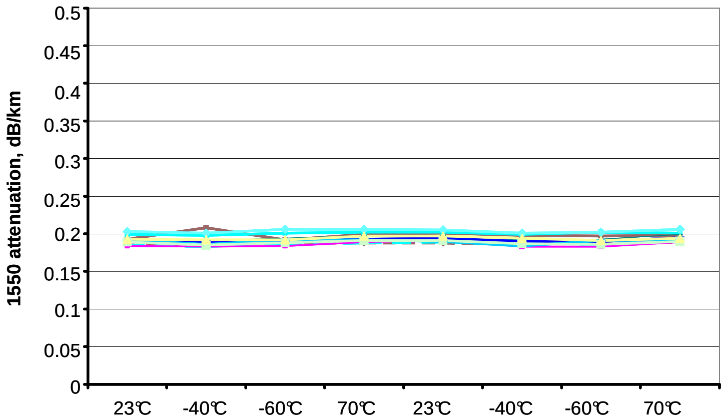

Fig. 5 Temperature cycling test

Alternatively micro-bending behavior can be evaluated by performing the above test method combined with a measurement of wavelength range rather than measuring on a single wavelength. The results of that test are shown in the Figure 6. Of major interest there is that also fiber types are compared. Then, combining the most micro-bending insensitive coating with the most macro-bending insensitive fiber type (Draka ***BendBright-XS***) results in almost un-measurable micro-bending attenuation, even at very high wavelengths (1700 nm).

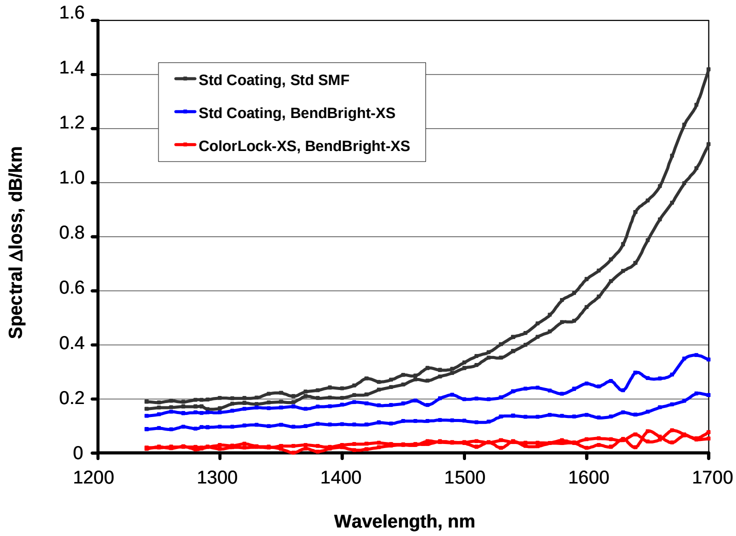

Fig. 6 Sandpaper drum spectral micro bending test

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3.c. Testing: Strip-ability

Strip-ability

In order to get smooth stripping and comfortable handling of fiber ribbons and tight buffered fibers, the adhesion of the new ***ColorLock-XS*** coating is lower compared to most commercial coatings. Strip force measurements on fibers with the new ***ColorLock-XS*** coatings have been made on both unaged and aged fibers to investigate strip force stability. All strip force measurements were performed according to IEC 60793-1-32: EIA/TIA-455-178 at a strip speed of 500 mm/min. Results are meeting IEC 60793-2-50 strip force requirements. They also proved that the new ***ColorLock-XS*** coating was stable after exposure to harsh environments. It is also noteworthy that in none of the measurements any remaining particles were found on the glass surface. A clean surface is important as it avoids contamination and misalignments during (mass)-splicing and or patch cord production.

Delamination resistance

ColorLock-XS features a low & stable strip force, indicating a stable adhesion of the primary to the glass. The adhesion stability can also be tested by monitoring attenuation while exposing fiber to a specific harsh environment. If adhesion would be affected delamination of the coating could occur resulting in a dramatic increase in attenuation. A typical test that distinguishes this behavior is the ribbon 60℃ 30 days watersoak test which is demonstrated in paragraph 3.a.

4. Conclusion

ColorLock-XS fiber coating is now made available, as the most superior general coating for all Draka single-mode optical fibers. ***ColorLock-XS*** is the latest advance in a story that began with the introduction of ColorLock more than a decade ago. ColorLock and new-generation ***ColorLock-XS***, uses a Draka-patented technology to color the fibers during the manufacturing process, at the drawing step. This means that the standard identification colors are directly integrated inside the fiber coating rather than applied with ink on the coating surface afterwards. The advantage is that colors appear brighter, they are always consistent and they are guaranteed not to wear or fade, which means they will maintain clarity and vibrancy for as long as the fiber lasts.

ColorLock-XS takes these benefits to a new level with:

- A significantly enhanced micro-bending performance
- Significantly improved strip-ability, unaged and aged
- Improved resistance to delamination;
- Resistance to aging in water, moist air, gel at high temperatures
- Visibly punchier, more vibrant colors: bright colors that are visible on dark and light background and under poor lighting condition

Draka fiber with ***ColorLock-XS*** remains the only optical fiber in the world that is proof-tested *after* being colored. The process guarantees true life expectancy of the fiber inside the cable, which is of paramount importance to the end-customer.

ColorLock-XS brings new benefits to every aspect of the value chain, which is a significant contribution to minimizing total cost of ownership. Speedier and easier installation, less re-work, less maintenance and a long life, all lower operational costs for network operators.

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