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New optical fiber for short distance network and elevated temperature environment

Valery Kozlov
Science & Technology
Corning Incorporated
Corning, NY USA
kozlovva@corning.com

Abstract **- New bend insensitive multimode optical fiber with a core diameter of 80 µm, numerical aperture of 0.29, and mid temperature acrylate coating (operating temperatures up to +200 °C) is proposed for short distance networks with a bandwidth of 10 Gb/s or more for distances up to 100 m.**

Keywords - glass optical fibers; bend insensitive fibers; mid temperature fibers; short distance network; temperature aging

I. Introduction

Optical fibers for short distance networks are the center of development today for two reasons: FTTH and in-house network applications are growing. For the latter, there are two types of connections in consumer homes today: broadband signal distribution (Coax, Wi-Fi, etc.) and interconnects between consumer electronics devices (USB, HDMI, etc.). Currently, in-house signal distribution solutions support data rates < 1 GB/s. Extrapolation of historic trends point to an increase to 10 GB/s by the end of this decade. Consumer electronic devices used today interface with data rates approaching and exceeding 10 GB/s. Two influential forces behind high speed interconnects are: video and transfer of large files from storage and media devices. Bandwidth requirements for high resolution displays drive the need for high capacity video cables. Optical fibers could provide: higher speeds (> 10 GB/s), longer reach, low cost, and thinner cables.

Optical fibers used in consumer homes require > 10 GB/s over in-house distances, larger core size (with limits to match the receiver size) and numerical aperture (NA), low bend loss, and mechanical reliability at sharper bends. Existing plastic optical fibers provide easy coupling, but high attenuation and high bend loss. Single-mode fibers support high bandwidth and small bends, but transceivers are more expensive. Existing multimode fibers (62.5 µm core diameter with NA = 0.275 and 50 µm core with NA = 0.20) could support OM1-OM4 bandwidth standards and could be bend insensitive, but these parameters are not optimized for link loss budget for typical VCSELs and PIN detectors and other link components. Link loss modeling demonstrates larger core size and NA should be used.

II. New Optical Fibers for Short Distance Network

Corning Incorporated developed ClearCurve® VSDN® fiber with 80 µm core diameter and NA = 0.29 for consumer electronics applications. Bandwidth was optimized for 850 nm wavelength to support 10 GB/s speed over > 30 m distance. A cross section of this fiber is shown in Figure 1. Fiber glass diameter was reduced to 100 µm to improve optical fiber reliability at extreme bend conditions (stress reduction by ~22% vs. 125 µm fiber). Specialty hard coating increased diameter to 125 µm for comfortable use of the existing fiber ferrules and connectors. Minimum bend diameter was set at 3 mm. This design enables 3 mm cable diameter that maintains link robustness in case of temporary cable pinch or knot (up to 100 kN/cm) with induced loss < 2dB.

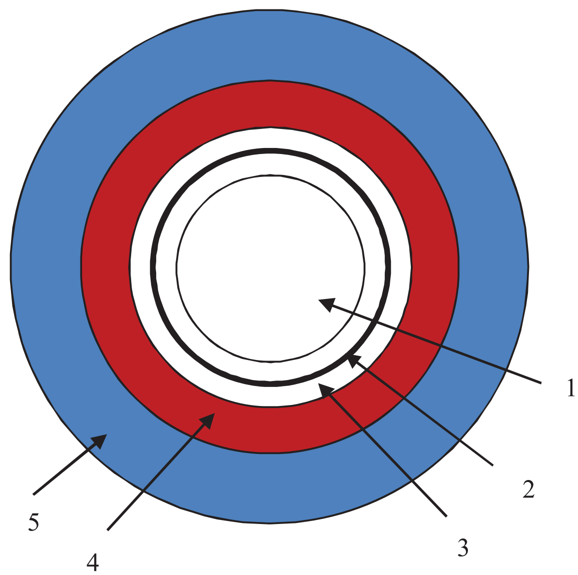

Figure 1. ClearCurve® VSDN® fiber cross section
1) 80-µm core; 2) refractive index trench position; 3) 100-µm cladding; 4) 125-µm hard coat; 5) 242-µm coating

On the basis of these development results, new mid temperature multimode fiber was designed. It has 80 µm core, NA = 0.29, and refractive index profile similar to ClearCurve® VSDN® fiber one to minimize fiber bend sensitivity, but this fiber has 125-µm glass cladding (100-µm cladding option is available as well) and mid temperature (MT) UV acrylate coating. Minimum recommended bend radius was defined at 5 mm. Coating system may be single coat (coating diameter of 200 µm or 245 µm) or dual coat (coating diameter of 245 µm). Several versions of this bend insensitive (BI) optical fiber are available and could be identified through new product names: MM80BI-MT, MM80BI-EMT, and MM80BI-XMT with maximum operating temperature of 150 °C, 165 °C, and 180 °C, respectively. A cross section of the MM80BI-MT fiber is shown in Figure 2. Each fiber could be manufactured with carbon hermetic coating on the surface of the glass cladding to improve fiber performance in the

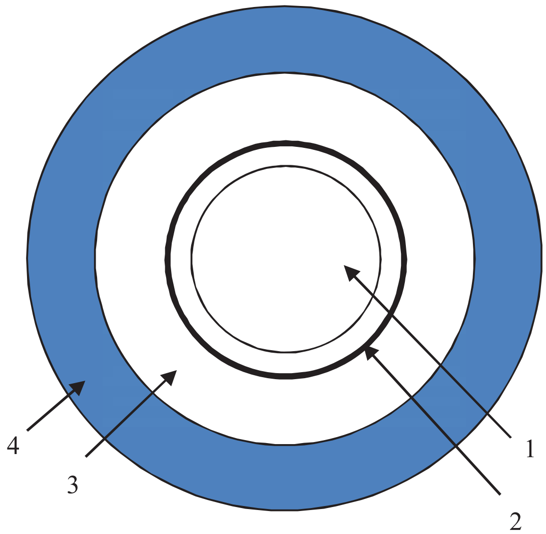

Figure 2. ClearCurve® MM80BI-MT fiber cross section
1) 80-µm core; 2) refractive index trench position; 3) 125-µm cladding; 4) 245-µm coating

presence of gases. Such fibers have the letter H added to the product name: for example, MM80BIH-MT.

III. Mid Temperature Coating Materials

Several different mid temperature coating materials were used in this development. All materials are UV cured, acrylate type materials which minimize differences between mid temperature and telecom grade optical fiber manufacturing and handling (stripping, cleaning, recoat). Hermetic carbon coating may also be used with this mid temperature coating system to prevent any gas penetration to fiber core (hydrogen especially) and improve optical fiber reliability due to fatigue reduction.

Performance of the mid temperature coatings was tested over multiple temperatures and exposure times. Test temperatures of up to +200 ºC and temperature aging times of up to 6000 hours were used. The optical fiber attenuation, strength, macrobend sensitivity, and other parameters were monitored for time and temperature stability. Temperature cycles -60 ºC to +180 ºC were used as well. It is important to note all elevated temperature agings were done in a normal, lab atmosphere.

Several experimental plots below demonstrate new coating material performance at elevated temperatures.

Figure 3 presents single-mode (SM) optical fiber attenuation (measured at 1550 nm wavelength) stability during temperature aging at 200 ºC. Three dual coat systems were used to make fiber samples. Attenuation was measured at room temperature after 1000 and 2000 hours of temperature exposure.

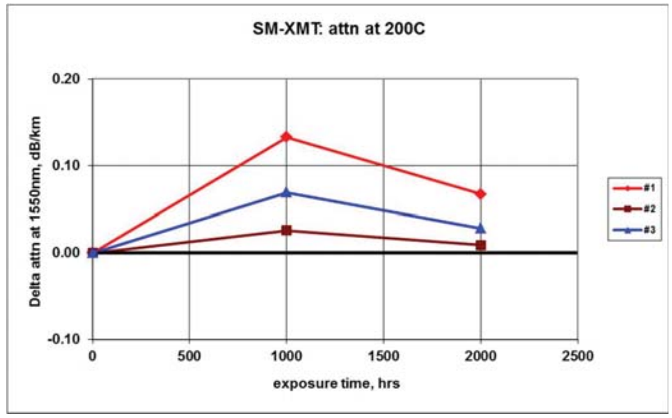

Figure 3. Attenuation stability for SM-XMT fiber samples at 200 ºC.

Attenuation variations are mostly connected with fiber handling during the test because similar results were measured at 180 ºC, 165 ºC, and 150 ºC attenuation stability tests. Maximum test duration for attenuation stability was 6000 hours at 180 ºC.

The strength of optical fiber samples was measured at room temperature as well as after exposure to elevated temperatures in a temperature chamber. Figure 4 shows test data for two SM-XMT fiber samples after 1000 hours of elevated temperature exposure at 200 ºC. Fiber strength was not affected.

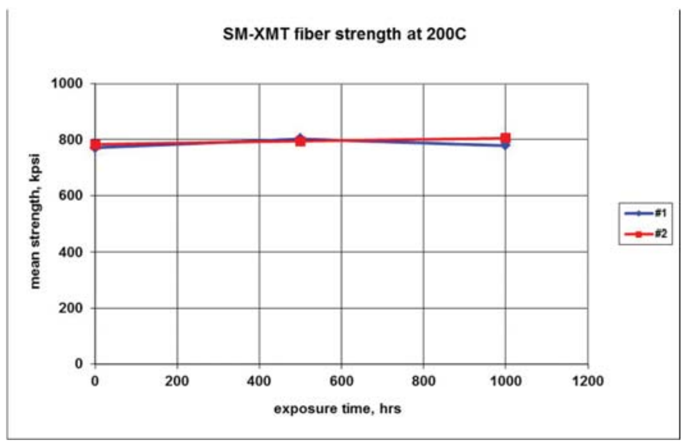

Figure 4. Optical fiber strength for SM-XMT fiber samples at 200 ºC.

So, developed coating systems allow good mid temperature fiber performance beyond development target temperatures in the range of 150 ºC – 180 ºC.

A temperature cycle test was done for three SM-XMT fiber samples with three different coating systems, each dual coat design. 800-m loose coils were used and the temperature chamber was programmed to run two cycles from -60 ºC to +177 ºC. Start temperature was 23 ºC (room temperature), then it was changed to 85 ºC, then to 177 ºC, back to 85 ºC, room (23 ºC), then to -40 ºC, to -60 ºC, and back to room

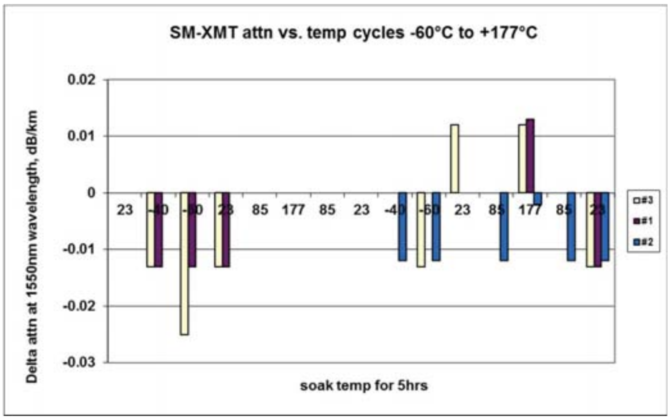

Figure 5. SM-XMT fiber sample attenuation stability at 1550 nm wavelength vs. two temperature cycles -60 ºC to +177 ºC.

again. These temperature changes were made during one temperature cycle. The second cycle was identical to the first. Dwell time for each of the indicated temperatures was 5 hours. Temperature rate for transitions was ~ 1 ºC/min. Test results are shown in Figure 5. All measured attenuation deltas at 1550 nm wavelength for two temperature cycles are shown and they are relatively small. Maximum temperature (+177 ºC) in this test was limited by temperature chamber specification.

IV. New Optical Fiber Performance

Newly developed multimode fiber with 80 µm core and NA = 0.29 could be used with any of the developed coating systems, single coat or dual coat. Respectively, new fiber product operating temperatures could be extended up to 200 ºC.

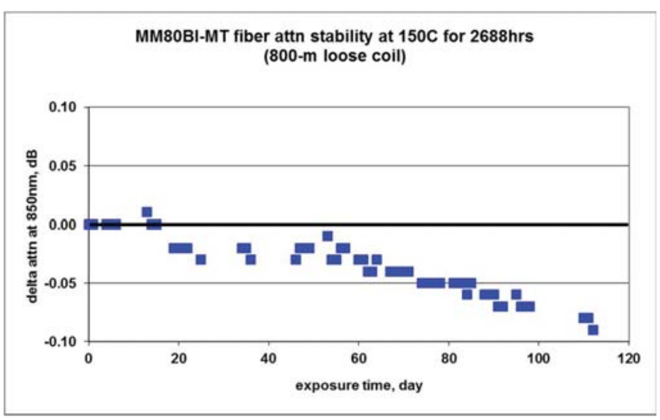

Figure 6. MM80BI-MT fiber sample attenuation stability at 850 nm wavelength and temperature of 150 ºC.

Tests for MM80BI-MT fiber samples were targeting this fiber attenuation and bend sensitivity at elevated temperatures to check new waveguide design temperature stability. All measurements were done at 850 nm wavelength.

The first MM80BI-MT fiber sample was wound in loose coil with total fiber length of 800 m and online attenuation test at 150 ºC was performed. The fiber sample was placed into the temperature chamber and two fiber feed through ports were used to launch and detect optical signal through the sample. Fiber handling was excluded in this test. Figure 6 shows test data for almost 2700 hours (112 days). No substantial attenuation change was measured.

Bend sensitivity temperature stability was measured for the bent fiber sample: two turns of MM80BI-MT fiber were wound on a 10 mm mandrel (bend radius of 5 mm) and this fixture was placed into a temperature chamber for an online attenuation test at 150 °C. Test data for more than 3200 hours (136 days) is shown in Figure 7. Fiber sample bend sensitivity did not measurably change during this test.

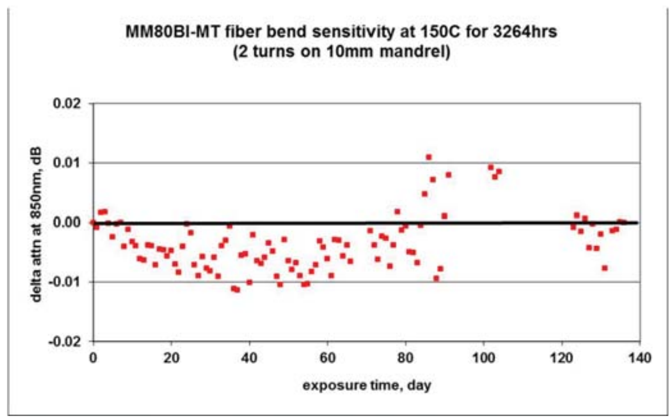

Figure 7. MM80BI-MT fiber sample bend sensitivity at 150 ºC.

Conclusion

The designed fiber with optimized waveguide structure for low loss links, minimal bend sensitivity, large bandwidth, specialty coating and using readily available transceivers would be the best choice for short distance networks operating in harsh environments. In order to achieve this, the current fiber design was made optically compatible with Corning Incorporated's recently launched consumer electronics optical fiber, ClearCurve® VSDN® fiber which was designed to support consumer applications with ultra-low bending loss and bandwidth of 10 Gb/s or more over up to 100 meters while enabling loose alignment tolerances to transmitter, receiver, and expanded-beam connectors.