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Cable Assemblies with ClearCurve® Multimode Fiber: End-Face Visual Effects

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This Applications Engineering Note (AE Note) discusses the methods available for visualizing connector end-faces that contain Corning® ClearCurve® OM3/OM4 multimode fiber (also referred to as "ultra-bend performance" multimode fiber), and the particular visual effects encountered during visualization of this type of fiber.

Cable Assemblies with ClearCurve® Multimode Fiber

Corning Optical Communications' ultra-bendable cable assembly product portfolio include Pretium™ Low-Loss jumpers. These zipcord jumpers are available in riser and plenum versions with 1.6 and 2.0 mm leg options. Connector configurations include:

- LC duplex/ LC duplex
- SC duplex/ SC duplex
- LC duplex/ SC duplex

End-Face Visualization

End-face visualization refers to the process or means by which connector end-faces are viewed using prevailing fiber optic inspection equipment and devices. The primary intent of end-face visualization is the detection of superficial flaws ("scratches", "pits", etc.) or debris that may be present after polishing. These may or may not increase insertion loss or reflectance in a fiber optic connection. It is important to understand end-face visualization is not the final determinant in assessing if a connector is within defined optical power budgets and reflectance levels. This ultimately is determined by an optical test set, optical time domain reflectometer (OTDR), or other device that can quantify insertion loss or reflectance in terms of decibel (dB) power loss. However, end-face visualization is often used to screen suspect connector end-faces for additional testing, or to ensure connectors are clean for optimal insertion loss.

End-Face Visual Inspection Equipment

In interpreting end-face visuals it is important to briefly differentiate between the different types of inspection devices available. Fiber "scopes", as they are commonly called, can be broadly classified into the following categories: field microscopes, probes and bench-top video microscopes.

Field microscopes are typically rugged, handheld devices designed for use in the field, and non-laboratory environments. These scopes incorporate a magnifying lens, or lenses, and

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white light illumination for viewing the connector end-face through an eye-piece. The illuminating light can be "coaxial" (i.e. parallel to the axis of the fiber), or "oblique" (i.e. at some angle relative to the fiber axis). In general, coaxial illumination offers more direct views of end-face anomalies (such as scratches), while oblique illumination tends to optimize inspection of end-face cleanliness. Typical powers of magnification for field scopes include 100x, 160x, 200x, 320x, or 400x.

Probes are hand-held devices that incorporate a high-resolution digital camera, and mount directly to the connector ferrule for end-face visualization. Probes work in concert with software that allows dynamic real-time viewing and connect to a field OTDR, laptop, or other device with a display monitor. Typical magnification powers include 200x and 400x.

Bench-top, or "bench" scopes include a high resolution digital camera built into an integrated workstation. The workstation will include a digital microscope, monitor and accompanying software for more detailed analysis and interpretation of results. Bench scopes allow for an objective interpretation of end-face visualizations in the manufacturing and laboratory environment. Optical magnifications (after factoring in the video display size) can reach up to 1600x on a 17" monitor.

Multimode Fiber: Connector End-face Regions

Multimode fiber (MMF) can be grouped into two main categories according to its core diameter: 50 and 62.5 micron (μm). 50 μm is preferred in today's LAN and Data Center installations. For more information on multimode fiber and its applications, refer to Corning Optical Communications AE Note 75, "Selection of Multimode Fiber for Premise Applications".
Figure 1 depicts a schematic of a typical 50 um MMF connector end-face viewed with a fiber scope. The cladding usually appears as a darker region outside the lighter core. Depending on the ambient lighting conditions, whether or not the connector is backlit, and the specific fiber scope used, the actual image viewed through a fiber scope may differ from Figure 1. However, the three regions in Figure 1 should be observable for 50 um fiber (regardless of its index of refraction profile). The main area for inspection is the core region, which carries the majority of the optical signal. The cladding region is a secondary indicator of the connector end-face polish quality.

Analyzing specific surface marks, defects and other polishing effects is beyond the scope of this document, but is generally defined by individual manufacturer and/or industry specifications (e.g. IEC/PAS 61300-3-35).

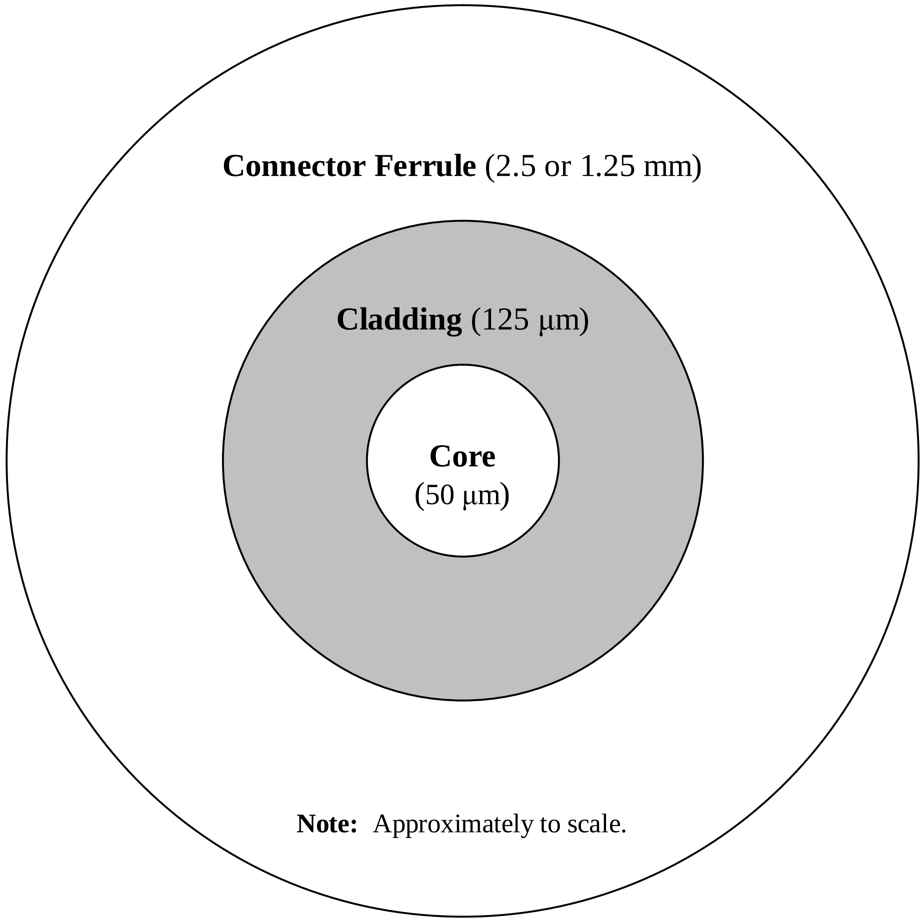

Figure 1: Multimode (50 um) Connector End-face

Connector End-face Visuals: Ultra-bend Performance Effects

The emergence of ultra-bendable laser-optimized™ multimode fiber (both OM3 and OM4 Corning® ClearCurve®) has enabled cable assemblies to offer macrobending performance that allows tighter bends in today's enterprise installations and environments. Cable assemblies containing ultra-bendable fiber accomplish this while also maintaining lower signal loss over conventional multimode fibers. Corning's ClearCurve multimode fibers are fully compatible with current industry standard multimode fibers, equipment, practices and procedures. The question may arise on how such fiber types will be observed during end-face visualization and how any appearance differences should be correctly interpreted. The answer, as it remains for any multimode fiber type, is that it depends on the ambient lighting conditions, the angle of incidence of the illumination light on the end-face, and the specific fiber scope used. If any differences are observed, it is important to distinguish between those that are inherent to the fiber design (i.e. those that do not degrade the connector performance) and those that are true functional defects, such as deep scratches that require further polishing. In the case of field microscopes and probes, no discernible differences are typically observed between an ultra-bendable MMF and a conventional MMF, as depicted in Figures 2 and 3.

If any difference is observed, it would most likely be a more intensely lit core in ultra-bend MMF due to its ability to confine more light in the optical core compared with conventional MMF.

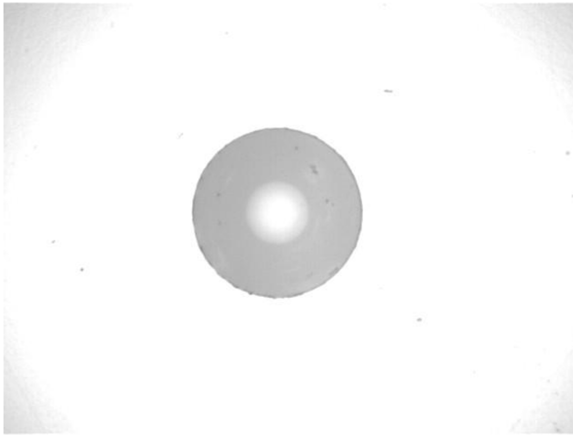

Figure 2: Conventional (50 um) MMF

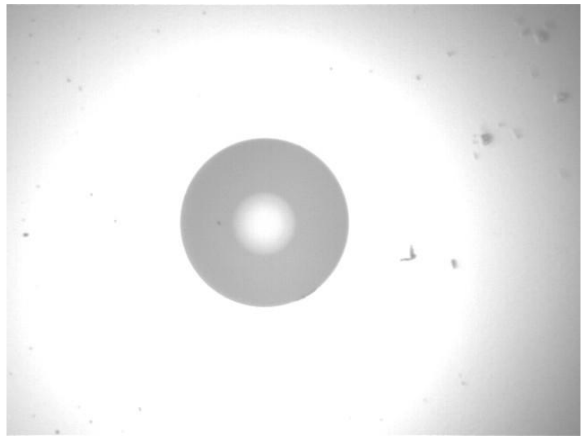

Figure 3: Ultra-bend (50 um) MMF

In the case of bench scopes, and once again depending on the specific equipment and set-up used, a faint ring, or “halo” in the cladding region may become apparent in an ultra-bend fiber due to its different index-of-refraction (IOR) profile. Figures 3 and 4 depict two separate images for conventional and ultra-bend MMF connector end-faces on a typical bench-top scope.

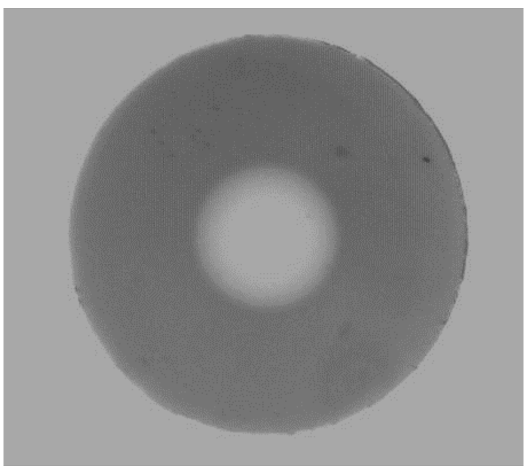

Figure 3: Conventional (50 um) MMF

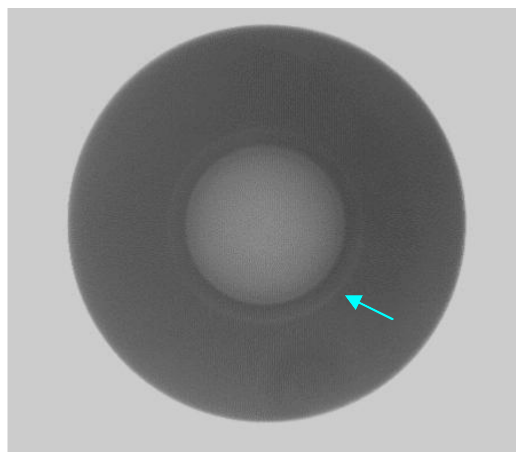

Figure 4: Ultra-bend (50 um) MMF

The arrow in Figure 4 depicts the location of the ring that may be visible with some bench-top scopes. This ring, or “halo effect”, is a by-product of the IOR profile that is designed into the cladding region of an ultra-bend MMF to improve bend-induced loss over conventional MMF. Note that that the ring is completely outside the light-carrying core region, which is the critical region of the fiber for transporting the optical signal. Figures 5 and 6 clearly illustrate the location of the ring relative to the core of an ultra-bend MMF.

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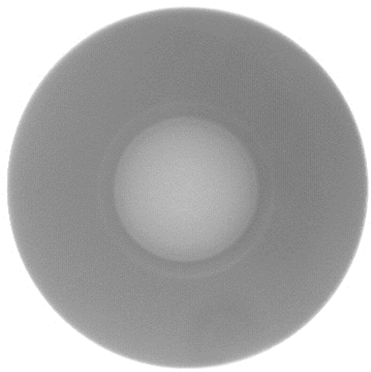

Figure 5: Ultra-bend End-face (front-lit)

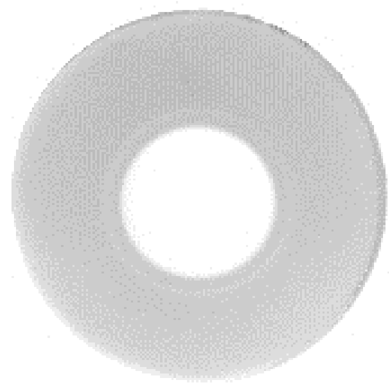

Figure 6: Ultra-bend End-face (back-lit)

Figure 5 is an image generated from a bench-top scope without injecting light into the MMF. Notice that the presence of the ring is outside the core region. Figure 6 is another image of the same fiber generated from the same bench-top scope with visible light entering and fully illuminating the core, indicating the relevant region for communication of optical signals. The ring is still clearly outside the 50 um region defined by the fully lit core.

Summary of Interpreting Results

Interpreting end-face visual images generated from prevailing fiber scopes can be somewhat subjective and dependent on the characteristics of viewing equipment. Some scopes will highlight particular fiber characteristics differently than others. The intensity of illumination light, its projection angle relative to the fiber axis, and other related optical effects pertaining to all microscopes combine to contribute to the overall image present in the field of view. A unique ring or halo may appear in the cladding region of ultra-bendable fiber with some types of fiber end-face inspection equipment. The appearance of a ring or halo depends on the scattering of the illumination light from the instrument being used. In essence, the unique structure and materials that define the IOR profile for ultra-bendable fiber are responsible for this observed phenomenon. It is this unique IOR profile of ultra-bendable fiber that enables industry-leading macro-bending performance (below 10 mm radius), setting it apart from other MMF types.

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