WHITE PAPER

Fiber optic patch cord performance and reliability

Your patch cord does not have to be your weakest link

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Most problems in any network happen at the physical layer. The first place experienced technicians begin their trouble shooting process is at the patch cord. Fiber patch cords are simple devices; (a length of fiber cable and a couple of connectors) but have a profound effect on overall network performance. Choosing patch cords that are more reliable can minimize costly and disruptive network down time.

Your patch cord does not have to be your weakest link.

Industry specifications govern the quality of patch cord material and performance. These specifications would include Telcordia GR-326, ANSI/TIA/EIA 568-C.3, TIA/EIA -604 series as well as governing standards published by IEC (International Electrotechnical Commission). In addition to performance, environmental and mechanical tests are detailed in each specification.

Service life testing required by Telcordia GR-326 include thermal cycling and the introduction of moisture into the system. Patch cord materials expand and contract differently within temperature ranges. Epoxy, metal, ceramic and glass will intersect at a single critical point behind the ferrule. Thermal cycling will expose any weaknesses in the termination. This test will reveal fiber "pistoning" or movement within the ferrule if the design and termination procedures are not optimal.

There are various mechanical tests detailed in industry specifications to confirm that fiber patch cords can survive the realities of use in the field. These would include twist testing; flex testing, cable retention, vibration testing, impact testing, durability, and transmission with an applied load. Any weaknesses in components or termination procedures would be revealed during these tests. Fiber patch cords need to withstand pulling forces incurred during installation. ANSI/TIA/EIA 568-C.3 provides a "strength of Coupling Mechanism" test. If a fiber patch cord receives an abrupt tug after installation, these tests serve to insure that the cord will not break or pull out of the adapter.

A durability test is applied to simulate the repeated use of the connector. In this test the connector is continually inserted in the adapter or jack. This test would reveal any design or material flaws in the connector or the latching mechanism during heavy use.

Building quality

A quality assurance system needs to be in place in a production environment to yield consistently reliable fiber optic patch cords. All production steps require documented procedures to monitor each phase of the process. To confirm compliance to established procedures, periodic audits are performed by specialists from outside the organization. ISO 9001-2008 registration provides the fundamental framework to accomplish this.

Fiber optic patch cords are typically tested for insertion loss and return loss, but there are many other factors which need to be monitored to insure the reliability of each cord.

Special fiber optic production tooling requires periodic maintenance and has a limited life on the production floor. This is critical for tools used for stripping, cleaving and crimping. If the tool used for stripping the fiber's buffer is dull, the fiber will be over stressed in the process. When a cleaving tool is worn, a clean score cannot be made. This results in non-uniform fiber breakage during the cleave, which can cause broken or cracked fiber below the ferrule end face. This means the connector should be scrapped. Crimp tools require periodic maintenance to insure that required forces are applied and crimp dimensions are consistent. Epoxy build up on crimp dies can cause too much pressure on the fiber and increased return loss.

The quality assurance system establishes the integrity of the incoming materials and all manufacturing processes. The conformity of these materials not only has a strong effect on product reliability, but also affects the performance of fiber patch cords.

Patch cord performance

There are a large number of issues that affect the performance of fiber optic connections in today's networks. These factors are increasingly important as data rates, the number of wavelengths and transmission distances continue to escalate. *The fiber optic patch cord should not be the system's weakest link.*

While there are several technologies on the market for fiber optic connectors, the vast majority utilize a cylindrical ferrule to capture the fiber. Each ferrule is then aligned to another ferrule through a precision sleeve. In order to ensure good contact, these ferrules are typically pressed together by means of a spring housed inside the connector. The force of these springs is about 0.9 kg. Since the force is applied to an extremely small area, it causes ferrule deformation and proper fiber to fiber contact. See figure 1:

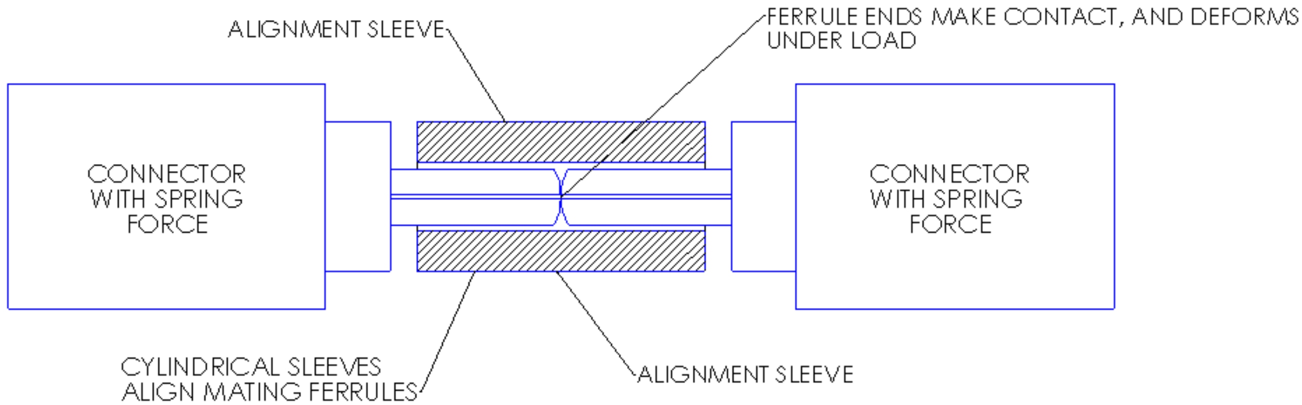


Figure 1: Cross-section of an interconnection

The main function of any connector/adapter is to align two ferrules, which in turn aligns the two mating fibers. No matter how well this is accomplished there are other forces working against good alignment. Lack of concentricity on the ferrule is considered to be the leading contributor to insertion loss, and the concentricity of the fiber's core to cladding can add to misalignment of the fiber cores. Since the fiber core diameter is so small, the effects of the ferrule hole or the fiber core being off center can have a large effect on optical performance. See figure 2:

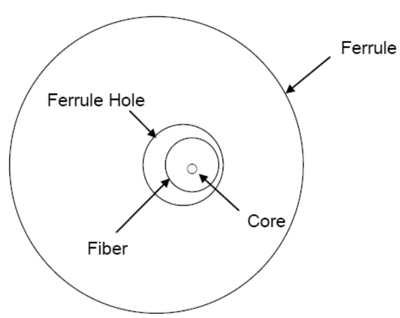


Figure 2: Component eccentricity (exaggerated)

The importance of end face geometry

The success of fiber optic connectivity in your network is ultimately dependent on the quality of the physical contact of the fibers. This physical contact is a function of the end face geometry of the fiber optic patch cord. If this end face geometry is not rigorously controlled, long-term network reliability is not assured. *The fiber optic patch cord does not have to be your weakest link.*

Telcordia GR-326 specifies three critical parameters for end face geometry: radius of curvature, apex offset, and fiber undercut/protrusion. Fiber optic patch cords that do not meet the parameters of this standard are at a greater risk of contributing to a system failure.

Radius of curvature describes the radius of the end face ferrule surface measured from its axis. Connectors use compression to keep the fiber end faces abutted. The curvature of the ferrule end face controls this compressive force to keep it centered where the fibers mate. Radius values outside the specified range increase the risk of fiber damage and reflection and insertion loss. See figure 3:

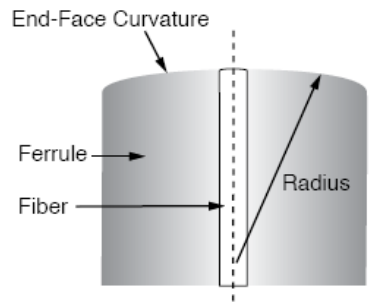


Figure 3: Radius Of Curvature

Apex offset is a measure of how far off center the highest point (or apex) of the rounded end face of the ferrule is to the center of the fiber core. It is important to minimize the offset so that the glass is truly at the highest point of the ferrule end. Because the offset can be in any direction, two mated connectors can have offsets that are additive. If the offset is too great, core to core contact will not be achieved, causing increases in insertion loss and reflectance over the operating range. See figure 4:

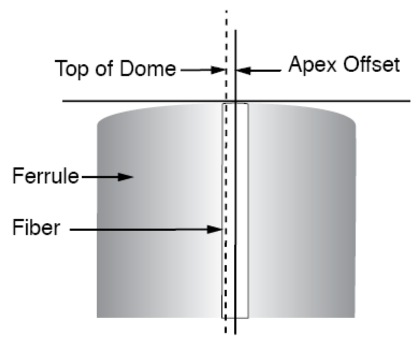


Figure 4: Apex Offset

Fiber height at the end face is described as undercut and protrusion. Fiber undercut is the distance of the fiber below the rounded end face of the ferrule. Its opposite is fiber protrusion, in which case the fiber juts above the ferrule end face. A proper undercut/protrusion guarantees that fiber to fiber contact will always be maintained over the operating temperature range, when materials can expand and contract. Extreme undercuts can result in air gaps between the connecting fibers' end faces, which lead to changes in reflectance and insertion loss. Excessive fiber protrusion increases the compressive load at the end of the fiber, causing damage or failure of the fiber-ferrule epoxy bond. In extreme cases, too much protrusion can cause a fracture in the glass and a catastrophic failure in the link. See figure 5.

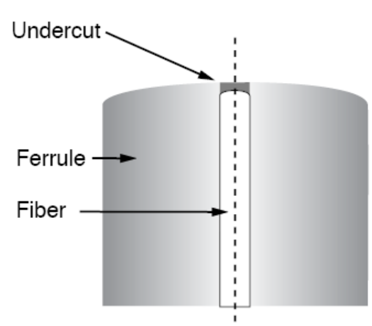


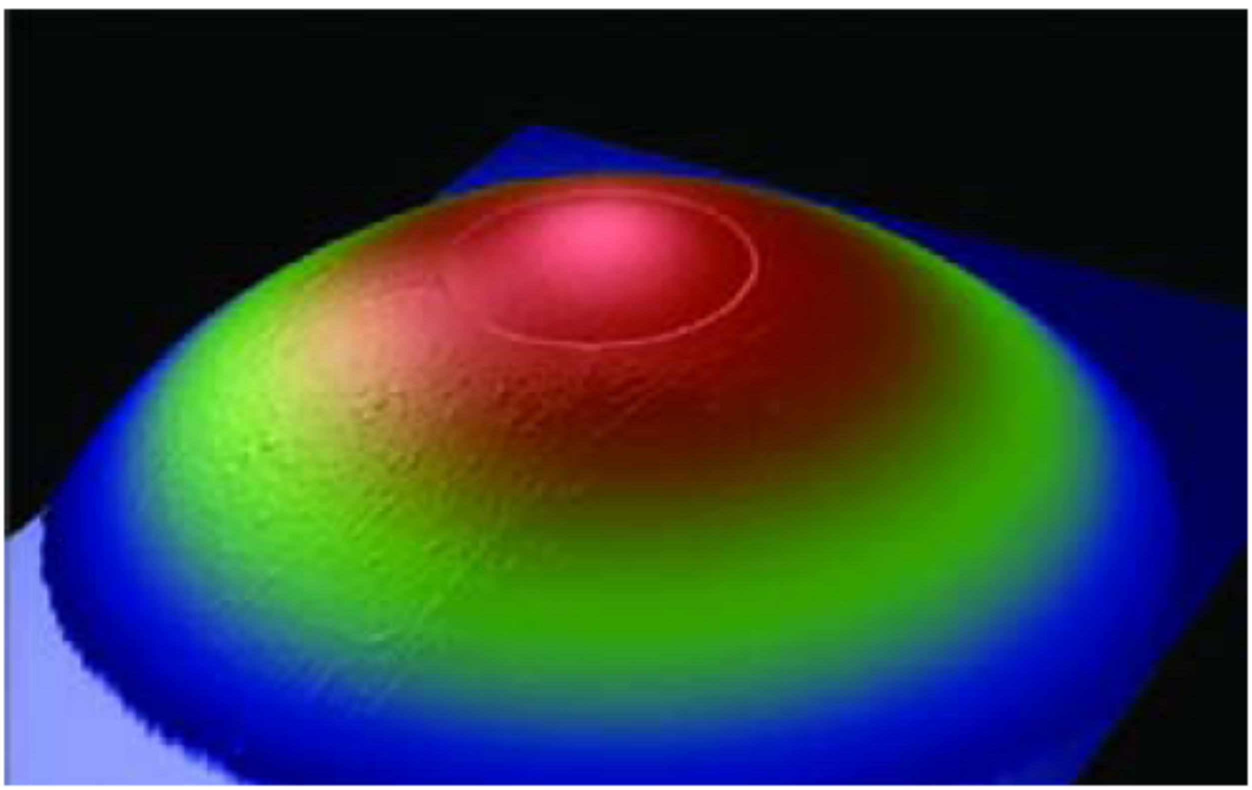
Figure 5: Undercut

Polishing

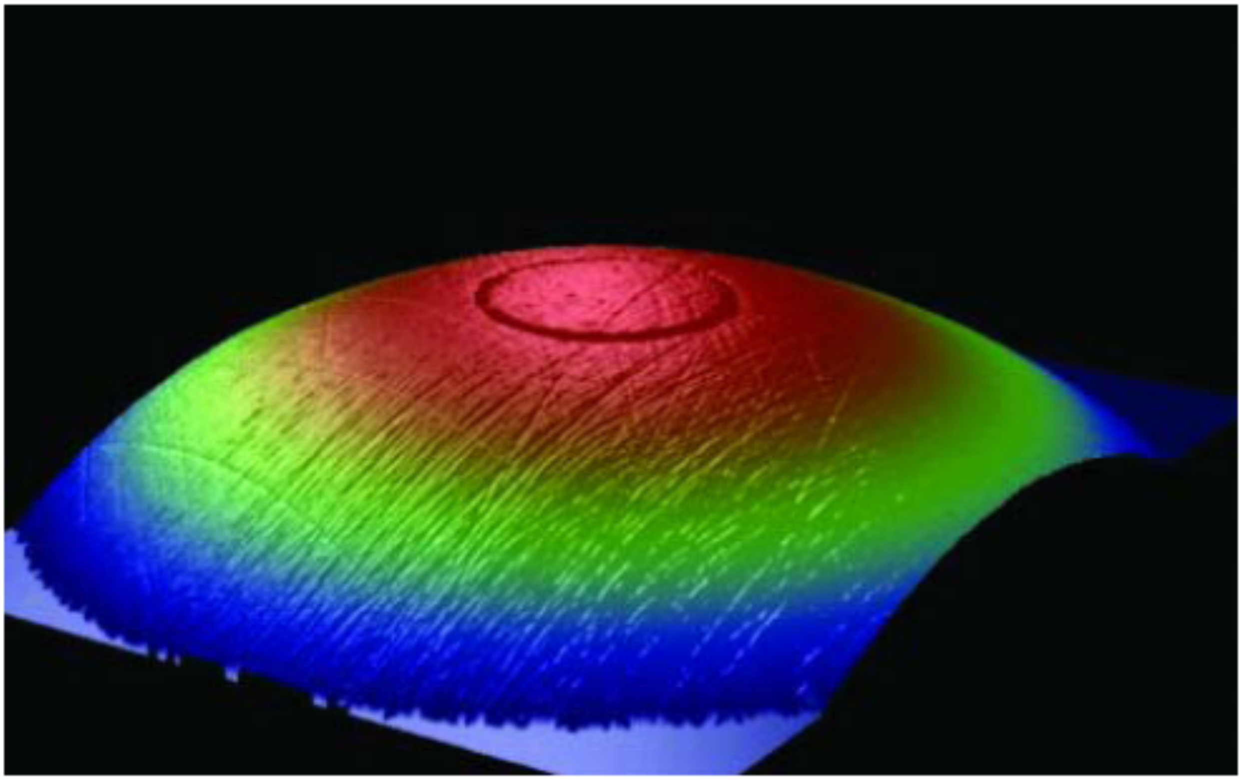
The end face polishing requires very tight tolerances in the manufacturing process. Polishing is done in multi-step procedures. The process is specified with polishing films, times and pressures. The first step is to remove epoxy from the ferrule's front surface, then form or keep the dome, and the final step is to shine the fiber surface. After polishing , the endface is inspected with a microscope or interferometer for remaining defects.

Poorly polished endfaces on fiber optic patch cords can spread problems through other network ports. Defects and scratches in the ferrule's contact area can act as reservoirs for contaminates. Likewise, a long scratch in critical mating areas can act as a capillary channel,through which contaminants and moisture can migrate. If the cord's end faces have extreme scratches or chips in critical areas, the compressive mating force can transfer these faults to other endfaces when ever the cord is mated to another port.

The polishing process should be acomplished in a clean enviornment, with professionally maintained tools, and state of the art inspection equipment.



Good Polish



Poor Polish

Conclusion

There is clearly a wide range of issues that affect the performance and reliability of a fiber optic patch cord. Unfortunately, typical end users do not have the time, specialized visual equipment or expertise to inspect the fiber optic patch cords that they purchase.

The reliability and performance of fiber optic patch cords is totally dependent on quality and process control in the manufacturing envionment. Performance documentation on the cords end face must be available for review. By understanding the process, and knowing the source of the product, sound purchasing decisions can be made.

Phoenix Optix adheres to all the standards and practices detailed in this paper; and consistantly achieves test results above the industry standards for insertion loss, return loss and end face geometry. *Your fiber optic patch cord does not have to be your weakest link.*

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