WHITE PAPER

Visual Inspection Anomalies of Fiber Stub Small Form-Factor (SFF)/Small Form-Factor Pluggable (SFP) Assemblies

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Visual cleanliness criteria have become an important aspect of optical product quality. In the last few years, automated inspection equipment manufacturers, engineers and scientists have faced challenges in determining what is considered acceptable cleanliness. Industry standards, including, but not limited to, IPC 8497-1, have summed up cleanliness criteria for different types of optical interfaces, including simplex, single mode (SM), multi mode (MM) and multiple port (MPO).

However, the success of implementing a repeatable inspection process is highly dependent on both the inspection tools used and the consistency of optical end-faces. This paper examines a phenomenon that has challenged the repeatability of semi-automated optical end-face inspection in regards to SFF/SFP fiber stub type Transmitter Optical Sub-Assembly (TOSA) devices.

Figure 1 shows a single fiber (Simplex) connector end-face consisting of a zirconia ferrule and a single optical fiber concentric to the ferrule. This type of end-face configuration is common in many connector types including, but not limited to: Subscriber Connector (SC), Lucent Connector (LC), and other variations of Ultra Physical Contact (UPC) and Angled Physical Contact (APC) connectors. It is also popular as an optical interface within SFF/SFP optical transceiver assemblies that employ fiber stubs as optical interfaces.

There is a good contrast between the ferrule (outer white portion) and fiber (center dark gray portion). Within the fiber itself, there is consistent gray shading. Any artifacts present on the end-face would show up as darker shaded areas, indicating dirt and debris. Artifacts might also appear as much brighter areas, depending on whether a metal has been smeared onto the surface of the end-face. Changes in contrast such as these are used by semi-automatic inspection systems to perform analyses and determine if the end-faces pass programmed criteria for particle count, size and location. These inspection systems are deemed “semi-automatic” because the test instrument’s focus and positioning are manual.

For camera systems to operate, the correct amount of light needs to reflect off the sample surface into the camera. In Figure 1, light is reflecting off the ferrule, causing it to appear bright and white. Light is also reflecting off the fiber, but to a lesser extent, causing it to appear a darker charcoal gray. A good portion of light from the source is actually absorbed by the fiber. Light captured by the fiber inevitably has to be emitted, or absorbed.

During the inspection of a fiber cable assembly end-face absorbed light, from the inspection system source, can be absorbed into the fiber via the coiled bends of the fiber, and/or partially emitted out the other end into free air, or into an attached dust cap or possibly another fiber assembly. If the emitting end-face is not appropriately mated, or terminated, a portion of light will reflect off the emitting end-face surface back into the fiber. This property is called back reflection and is caused by a change in refractive indices at the interface of the glass fiber to air.

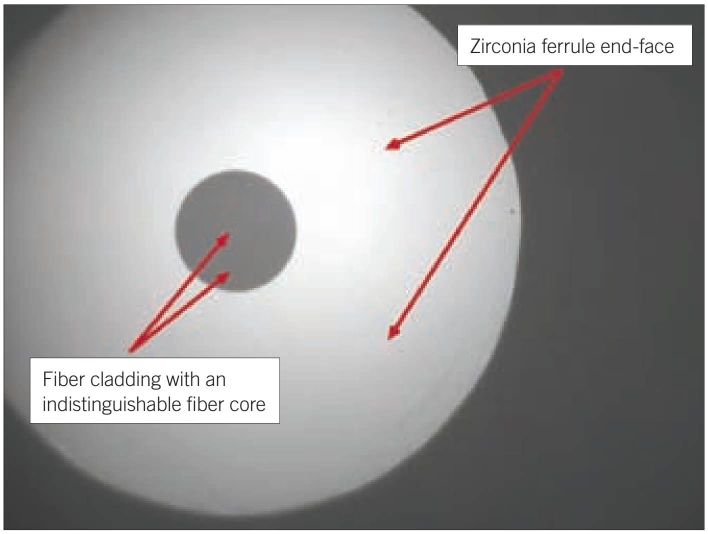

Figure 1.

Using an inspection scope, a non-terminated fiber-end will display this effect as a light spot in the center of a single mode fiber and as a frosty white spot in the center of a multi-mode fiber.

When fiber cables are lengthy, back reflection, from the illuminating source, may not affect inspection results as the reflected light may be absorbed along the fiber length. But what happens when the fiber length is very short, and physical construction supports the reflection of light back into the emitting end of a fiber?

Figure 2 illustrates the consequences of light being reflected back into a fiber stub off reflective surfaces within a TOSA device. The reflective surfaces may include the TOSA metallic canister, and a lens integral to the canister.

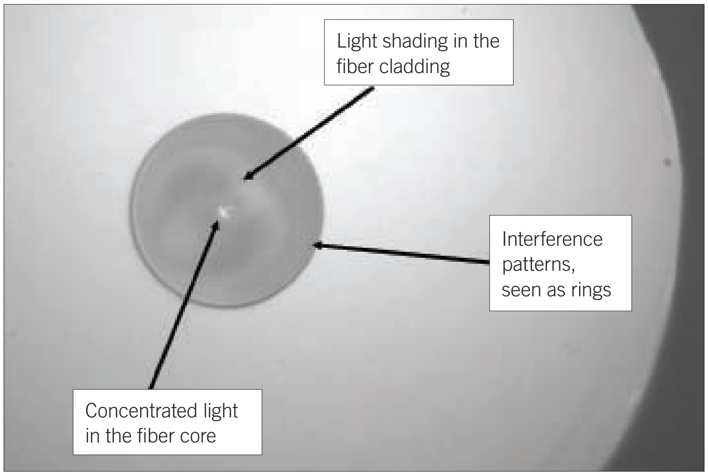

Figure 2.

Figure 2 illustrates evidence of back reflection. Rings (interference patterns) are present around the outer circumference of the fiber. Also, lighter areas of shading make the fiber cladding appear visually inconsistent. This phenomenon may create a problem for semi-automated inspection systems.

Figure 3 represents an actual inspection result from the end-face captured in Figure 2.

The inspection system has indicated false positives, highlighted in red on Figure 3. The failure sites mimic the interference pattern seen in Figure 2. This end-face is a known good end-face, as it is the same end-face illustrated in Figure 1, which passed inspection. To reproduce this phenomenon, the original TOSA device containing this sample end-face was disassembled. In doing so, a reflective surface could be placed directly behind the emitting end-face (internal end-face) of the TOSA fiber stub. Figure 1 illustrates light emission into free air, and Figure 2 illustrates light reflecting off a reflective surface back onto the fiber stub inner end-face surface.

Figure 4 illustrates an actual picture of an assembled TOSA end-face showing the back reflection phenomenon. The pattern only appears in approximately half of the available circumference, which is believed to be influenced by the angle of polish on the fiber stub inner end-face. The inner end-face angle may be in excess of 10 degrees.

In a production facility where inspection is carried out manually using transparent overlays to compare artifacts, a phenomenon such as this can be ignored. But when photo documentation and inspection results of optical end-face quality are required, the financial impact of this phenomenon may be significant.

False positives have mainly been associated with fiber-stub type end-faces within SFF/SFP assemblies. Not all manufacturers' fiber stub type SFF/SFP devices will demonstrate the phenomenon.
To a much lesser extent, back reflection has also had a negative impact on inspection results for shorter (<9 meter) multi-mode fiber cable assemblies. In the case of multi-mode fibers, the shading characteristics of the phenomenon are subtle, and not easily discernable by eye.

Current inspection system software may be adjusted to overcome this issue, but at a cost. Inconsistent variables, such as arc length, width, contrast and position, cause a portion of the fiber cladding to be "less inspectable" than other areas where contrast and gray scale shading are consistent. If software is modified to ignore the patterns, it may miss true artifacts, including large edge chips considered to be true failures.

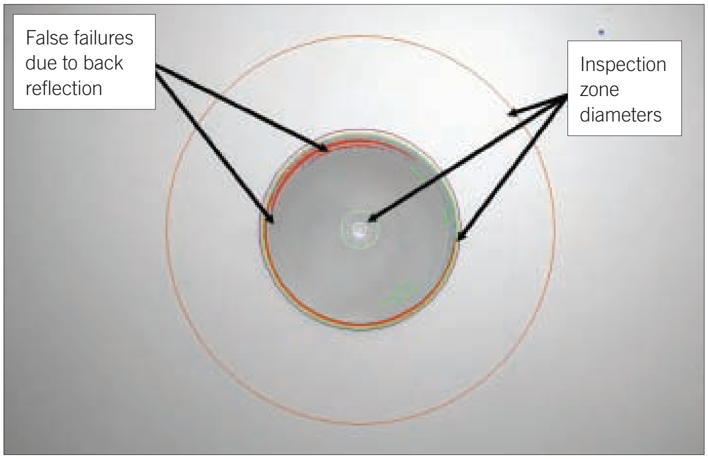

Figure 3.

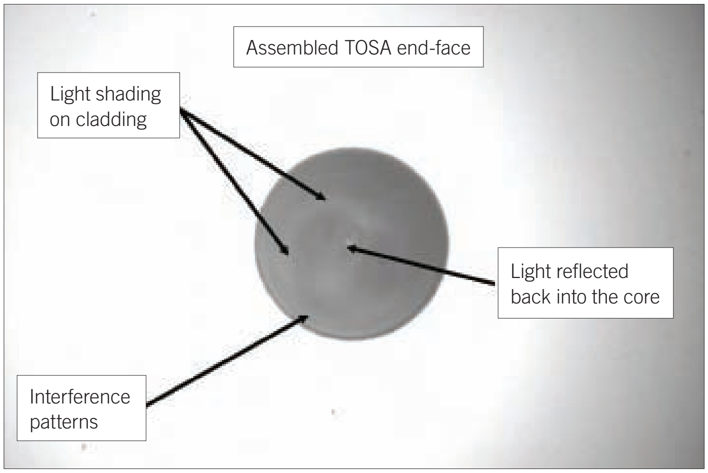

Figure 4.

Several possibilities for resolution may be explored. These methods include, but are not limited to, Anti-Reflective (AR) coatings used within TOSA devices or polarization and filtration techniques utilized within inspection equipment. As of now, the false positive issue has been addressed with a software modification. As this modification is only temporary, future advancements in optical interface technologies, including reductions in size, increased optical power handling capabilities, and finer surface finishes, are expected over time. The thoroughness of optical cleanliness inspections will have to follow suit. It is believed that the designers of optical inspection systems should expect more of these types of challenges as optical interface technologies progress.

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