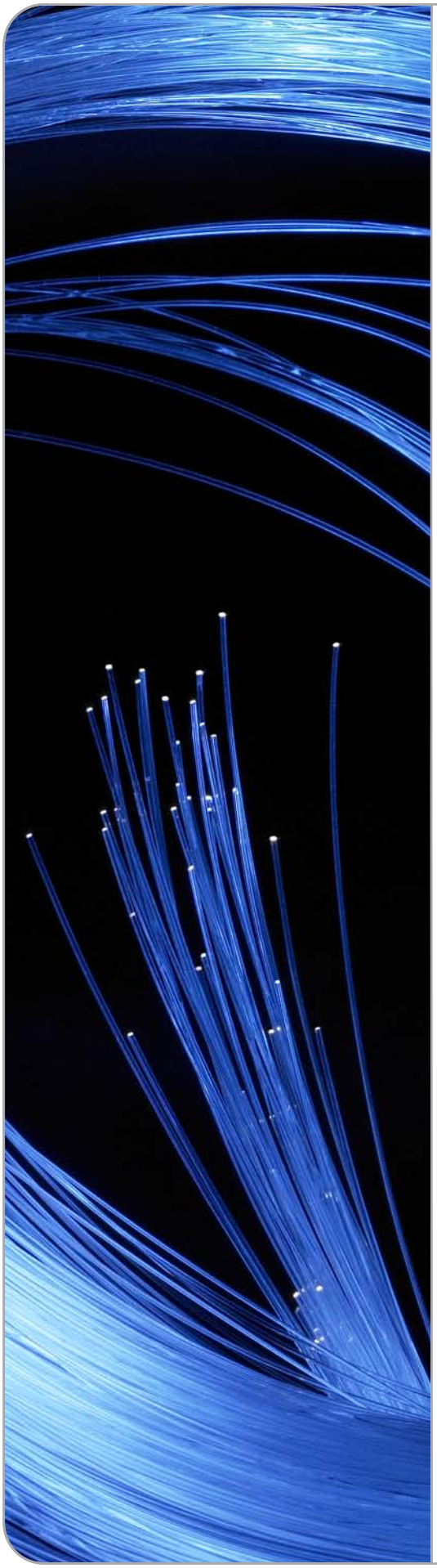


WHITE PAPER

Optical Connector

Endface Geometry

ADC KRONE

Optical Connector
Endface Geometry

Abstract

In order to achieve good reflectance performance through environmental and stress conditions seen in service, fiber-optic connectors must achieve and maintain physical contact between fiber cores. It is a given in the industry that ferrule endface geometry is critical to maintaining fiber core physical contact. The three critical attributes of endface geometry for physical contact (PC)connectors are radius of curvature, fiber protrusion/recession, and apex offset. In angled physical contact (APC) connectors, the equivalent of apex offset is often referred to as dome offset. ADC inspects and records endface geometry parameters on 100 percent of its singlemode highperformance optical connectors. The resulting geometry data is shipped with each patch cord.ADC maintains statistical process control on these parameters and demonstrates a high level of process capability, ensuring excellent connector performance in all expected network environments.

Introduction

Fiber-optic connector reflectance performance is dependent on maintaining good physical contactbetween the fiber core endfaces. Any air gap between the fiber cores causes significantreflectance[1]. Multiple variables that affect core contact in a mated connector pair include springforce, friction in the alignment sleeve, and ferrule length. Each of these has a direct effect on howthe ferrule ends are compressed against each other and historically has been fairly easy formanufacturers to control. However, a variable that also has a significant effect on core contact andhas not been as easy for manufacturers to control is endface geometry. This is due to endfacegeometry being an outcome of the endface polishing process and requiring very tight tolerances inthe manufacturing process.Endface GeometryThe three attributes of endface geometry are radius of curvature, apex offset, and fiber height.Radius of curvature is the curvature of the ferrule endface measured immediately around the fibercore. Apex offset is the offset distance between the fiber core axis and the apex of the radius ofcurvature. Fiber height is the distance between the ferrule surface and the fiber end. Positive fiberheight is often referred to as fiber protrusion, while negative fiber height is often referred to asfiber undercut (see Figure 1).

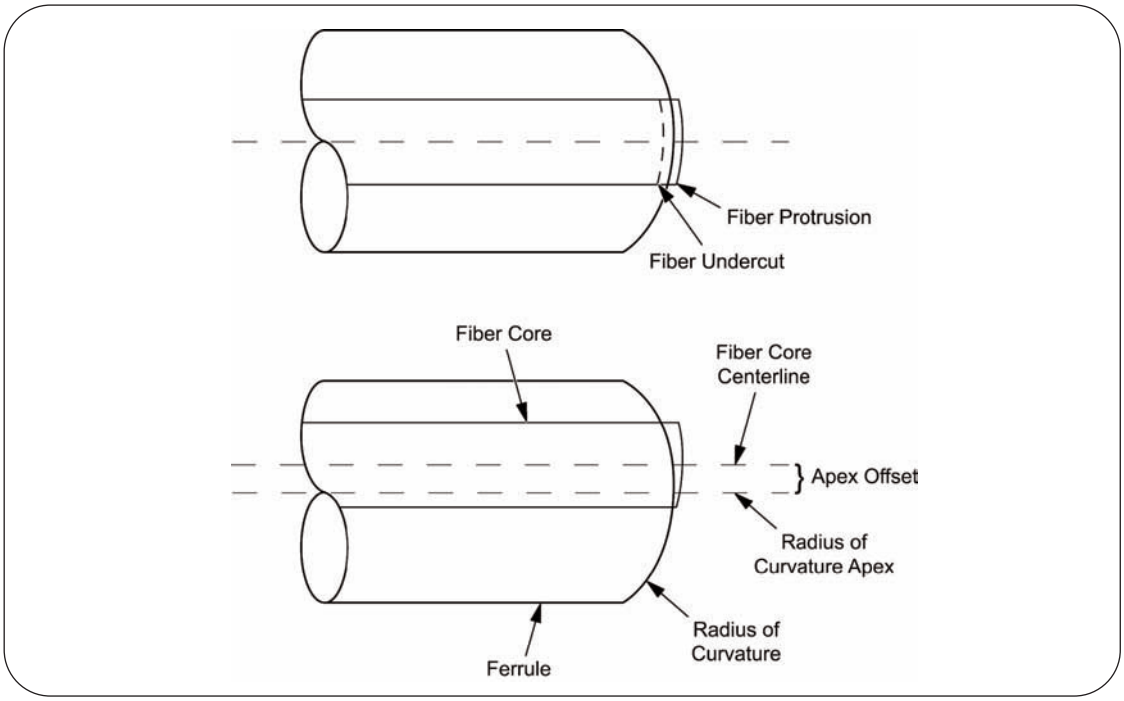


Figure 1. Endface Geometry Attributes

Optical Connector

Endface Geometry

During connector mating, there is compression of the ferrule ends and a deformation that allows forfiber core contact even if both connectors have fiber undercut. When any of the endface geometryparameters are not controlled, there are two possible negative outcomes. One outcome is that thefibers do not make physical contact. This would result in poor reflectance performance. Anotheroutcome would be that the fibers make physical contact but exert an unacceptably high load againsteach other. This could result in creep and permanent pushback of one of the fibers[2]. Permanentfiber pushback could result in failure to achieve good physical contact and hence poor opticalperformance in subsequent matings.ADC holds the following tolerances on endface geometry for PC connectors (SC and FC):

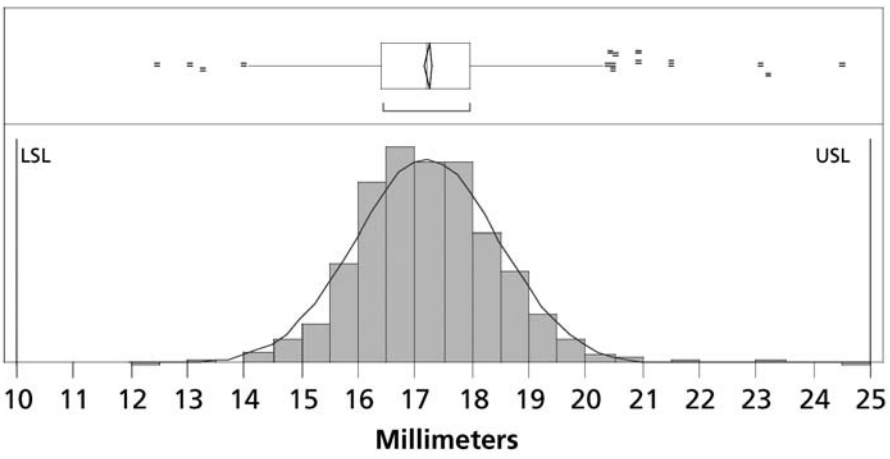
Geometry	Minimum	Maximum
Endface Radius of Curvature	10.0 mm	25.0 mm
Apex Offset	0.0 µm	50.0 µm
Fiber Height	-50.0 nm	50.0 nm

ADC's actual process distributions are well within the stringent requirements set forth in GR-326-COREIssue 3.

ADC Manufacturing and Test CapabilityADC inspects and records the values of endface geometry on 100 percent of its singlemode highperformance optical connectors. Any product that does not meet one of the endface parametertolerances is rejected and reworked. The recorded values are traceable with a barcode serial number.Inspection is done with an endface inspection device (interferometer) manufactured by Direct OpticalResearch Company. ADC verifies the accuracy and repeatability of all endface inspection devices in itsfacilities on a weekly basis.ADC developed the polishing process for the singlemode connector utilizing Six Sigma techniques. Theresults from this study permitted ADC to achieve excellent process capability for the three main endfacegeometry attributes. ADC worked closely with its material suppliers to develop the final polishing filmbest suited for the new process. During this study, the key inputs and outputs for each processing stepwere clearly defined and documented. The outcome was a polishing process that was very robust, costeffective, and easily transferable between ADC's facilities around the world. ADC has a patent pendingon its polishing processOther key items to achieving a world class polishing process include the implementation of aqualification program for tooling and an extensive preventive maintenance program for the polishingequipment. A company wide training program ensures consistent processing techniques betweenoperators across all of the ADC facilities. ADC performs statistical process control on endface geometry attributes and calculates the capability ofADC's polishing process for each of the attributes. The graphs on the following pages show adistribution from 795 UPC SC and FC optical connector ends produced on one of ADC's highperformance connector production lines.

Optical Connector
Endface Geometry

Radius



LSL: Lower Specification Limit Normal (17.2315, 1.26875) USL: Upper Specification Limit

Moments

Mean 17.23147

Std Dev 1.26875

Capability Analysis

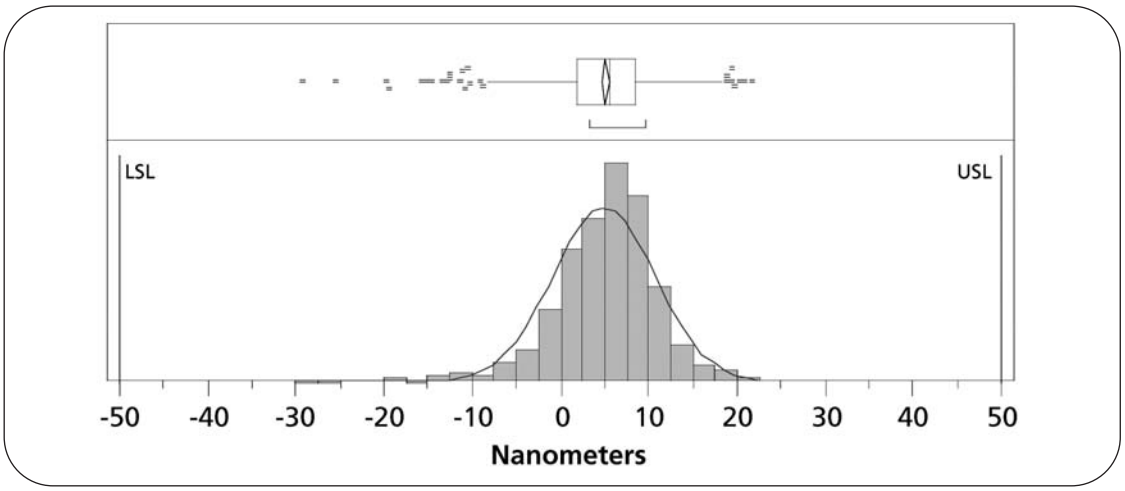
Specification	Value	Percent	Actual	Normal
Lower Spec Limit	10	% Below LSL	0.000	0.000
Upper Spec Limit	25	% Above USL	0.000	0.000
Spec Target				
Sigma	1.268752			

Capablity	Index	Lower CI	Upper CI
CP	1.970	1.874	2.067
CPK (PPK for AIAG)	1.900		
CPM			
CPL	1.900		
CPU	2.041		

Optical Connector

Endface Geometry

Fiber Height



LSL: Lower Specification Limit Normal (5.10189, 5.81121) USL: Upper Specification Limit

Moments

Mean 5.10889

Std Dev. 5.811209

Capability Analysis

Specification	Value	Percent	Actual	Normal
Lower Spec Limit	-50	% Below LSL	0.000	0.000
Upper Spec Limit	50	% Above USL	0.000	0.000
Spec Target				
Sigma	5.811209			

Capablity	Index	Lower CI	Upper CI
CP	2.868	2.727	3.009
CPK (PPK for AIAG)	2.575		
CPM			
CPL	3.161		
CPU	2.575		

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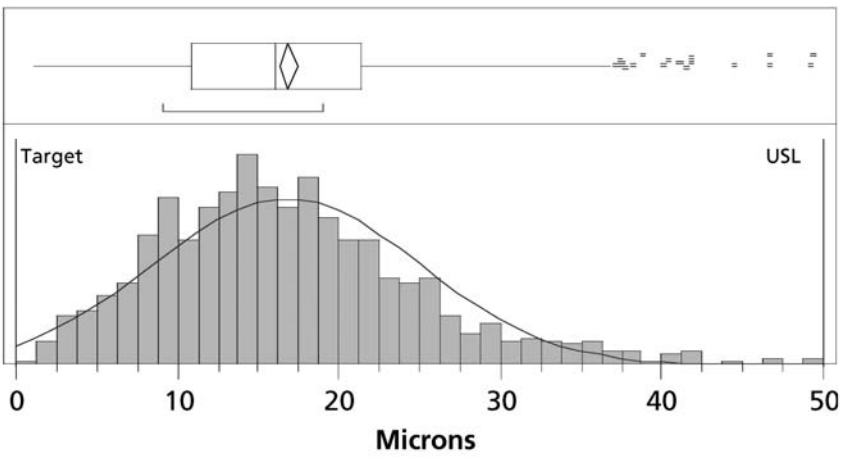
Optical Connector

Endface Geometry

Apex



Target Normal (16.8503, 8.2055) USL: Upper Specification Limit

Moments

Mean 16.85029

Std Dev 8.20550

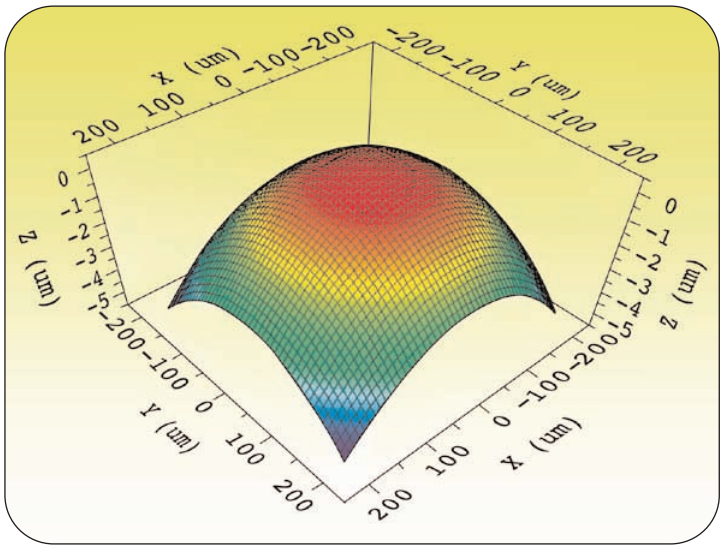
Capability Analysis

Specification	Value	Percent	Actual	Normal
Lower Spec Limit		% Below LSL		
Upper Spec Limit	50	% Above USL	0.000	0.003
Spec Target	0			
Sigma	8.205504			

Capablity	Index	Lower CI	Upper CI
CP			
CPK (PPK for AIAG)	1.347		
CPM	0.889		
CPL			
CPU	1.347		

Optical Connector
Endface Geometry

Ferrule Endface



3D-image of convex ferrule endface (UPC polish).
Result of interferometric inspection.

Summary

Fiber-optic connector reflectance performance is a direct result of achieving and maintaining goodphysical contact between fiber core endfaces. Variables affecting physical contact such as spring force,friction in the alignment sleeve, and ferrule length have historically been fairly easy for manufacturers tocontrol. However, a variable that has not been as easy to control is endface geometry. This is due toendface geometry being an outcome of the endface polishing process and requiring exceptionally tightmanufacturing tolerances.

The three critical attributes of endface geometry that contribute to reflectance performance are radius ofcurvature, fiber protrusion/recession, and apex offset. ADC maintains statistical process controls on eachof these parameters. ADC also verifies the accuracy and repeatability of all endface inspection devices inits facilities on a weekly basis. In addition, the endface geometry parameters of every ADC highperformance optical connector is shipped with each patch cord. Through these efforts ADC hasconsistently demonstrated the capability to produce excellent connector performance in all expectednetwork environments.

References

[1]Reith, L.A., Grimado, P.B., & Brickel, J. Effect of Ferrule-Endface Geometry on ConnectorIntermateability(NFOEC-94-2000-CD). Paper presented at the National Fiber Optic EngineersConference. New Jersey: Telcordia Technologies, Inc.

[2]Reith, L.A., Grimado, P.B., & Frantz, R. A., Plitz, I. M., Wood, W. W., & Dolinoy, D. A. Effects of FiberPushback in Ceramic-Ferrule Connectors on Connector Intermateability(NFOEC-94-2000-CD). Paperpresented at the National Fiber Optic Engineers Conference. New Jersey: Telcordia Technologies, Inc.

[3]Telcordia Technologies, Inc. (1999). Generic Requirements for Singlemode Optical Connectors andJumper Assemblies(GR-326-CORE, Issue 3). New Jersey: Author.

OPTICAL CONNECTOR

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