DEFINING AND MEASURING PHYSICAL PARAMETERS OF PC POLISHED FIBER OPTIC CONNECTORS

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ABSTRACT

The geometry of physical contact (PC), polished connector endfaces has been shown to play an important role in the performance of high quality, single mode, fiber optic connectors. Controlling parameters such as the radius of curvature, the apex offset and fiber height during the polishing process leads to more consistent performance. This is evidenced by reduced insertion and return loss during both immediate quality control testing and long term performance.

In order to improve consistency, repeatability and intermateability of product, the industry has defined standards and methods for measuring these characteristics of the endface. Some of these standards are presented here. It is hoped that this will help end users to improve the quality of their PC polished connectors and define a standard terminology for discussing endface geometry.

INTRODUCTION

Many papers have been published on the importance of controlling the polish geometry of a PC connector[1,2,3,4]. The evolution of this spherical type, connector endface polish brings new challenges for quality control as the specifications become tighter. In this paper we would like to review some of the definitions and standards which have been defined by the industry for these key parameters.

PHYSICAL PARAMETERS

One of the basic tenets of the PC polish design is to insure continuous fiber to fiber contact for intermating connectors while taking into account the effects of time, temperature, vibration and pressure. In order to accomplish this, the geometry of the spherical ferrule surface and the fiber must be known. At present, the geometry of these areas is characterized by three, key, physical measurements:

DEFINITIONS

1. **Radius of Curvature.** The Radius of Curvature is the radius of the sphere formed by the polished ferrule**.**

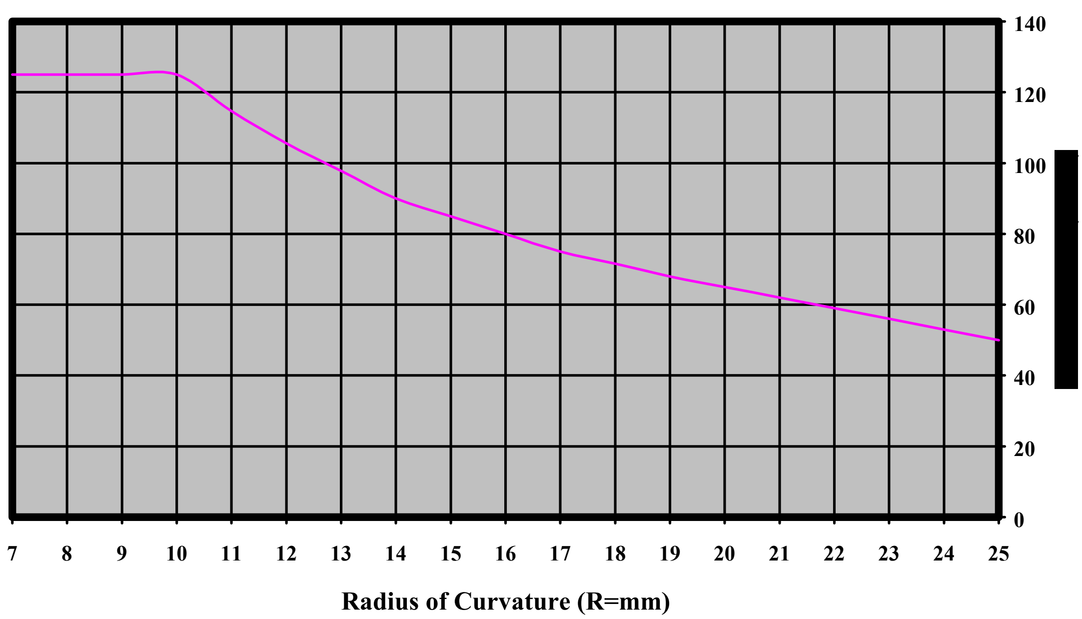
2. **Fiber Height** (similar terms: undercut or protrusion). The Fiber Height is the distance the fiber is extended out of or recessed into the ferrule.

3. **Apex Offset** (similar terms: offset of the polish, vertex offset, eccentricity of the polish or vertex eccentricity). The Apex Offset is the distance from the high point on the polish to the center of the fiber.

TYPICAL PHYSICAL PARAMETEERS FOR PC POLISHED CONNECTORS

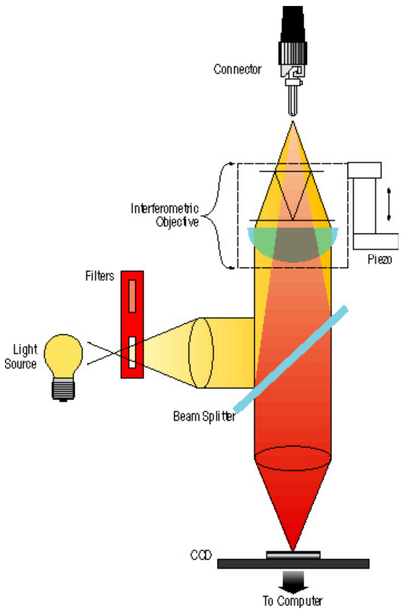
	PC		APC
	Telcordia[8]	**IEC[9]**	**Telcordia[8]/IEC[9]**
ROC	7-25mm	10-25mm	5-12mm
Apex Offset	<50µm	<50µm	<50µm
Protrusion	0.05µm	0.10µm	0.10µm
Undercut	(See chart below)		0.10µm

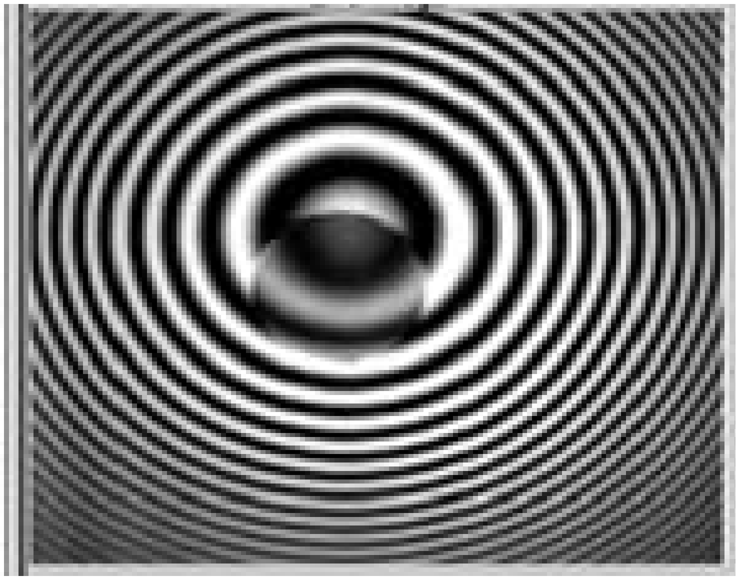
$U=-0.02R^3+1.3R^2-31R+325$



TEST EQUIPMENT

Before elaborating on these terms, it is helpful to describe the typical test equipment used to measure these physical parameters. Because of the three dimensional nature of the data, the interferometric microscope has become the instrument of choice for obtaining these measurements. The interferometric microscope uses a coherent light source to reflect light off the connector endface. This light is combined with light reflecting off a reference surface to form constructive and destructive interference waves. The resulting interference pattern can be visualized as a contour map of the connector endface with each dark fringe identifying a specific height on the surface.

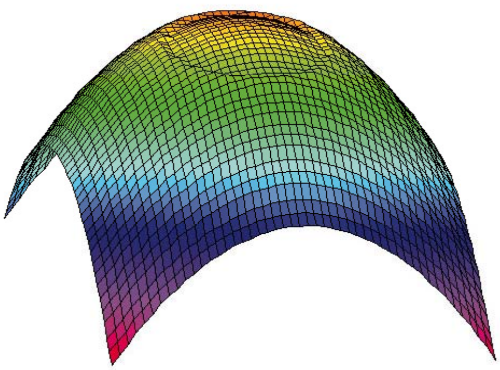


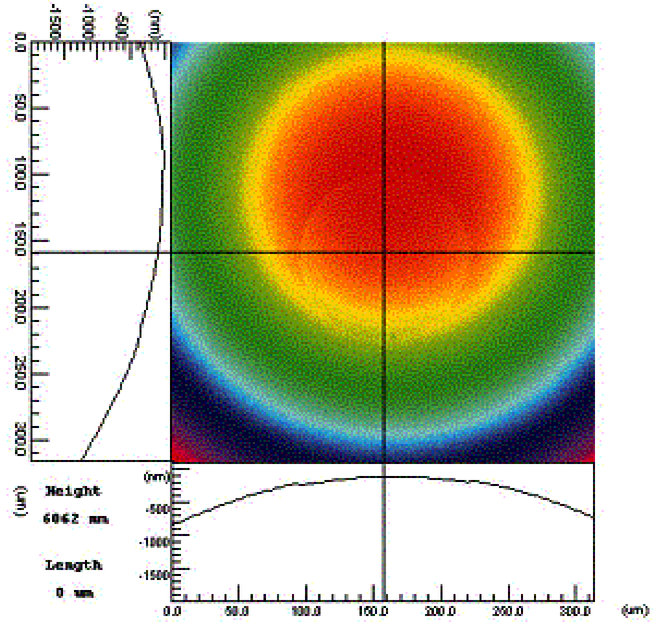


INTERFEROMETRIC MICROSCOPE

One type of interferometric microscope comes as a "turnkey" system with computer and monitor. It is designed for "ease of use" and does not require a high level of knowledge about interferometry.

Using a piezoelectric device to "shift" the interference pattern, it compares the changing images to the initial fringe pattern to determine the physical coordinates for every point on the surface[5]. As a result, the distance and direction between any points on the surface can be measured. Information can be displayed as a three dimensional wire mesh to visualize the entire surface or as cross sectional profiles for a simpler perspective.





3D MESH DISPLAY
helps the user visualize
the surface under inspection.

COLOR CONTOUR DISPLAY
provides a cross sectional view
anywhere on the surface.

IMPORTANCE OF MEASUREMENT AREA

When we look at an actual connector end face with an interferometric microscope, it quickly becomes apparent that it is not a perfect sphere. The radius of curvature changes with the distance from the ferrule axis. The fiber often has its own curvature above or below the surface of the ferrule.

The International Electrotechnical Commission (IEC) has suggested the definition of measurement areas to clarify the important features (Fig. 4) and minimize confusion[6]. The three areas suggested are:

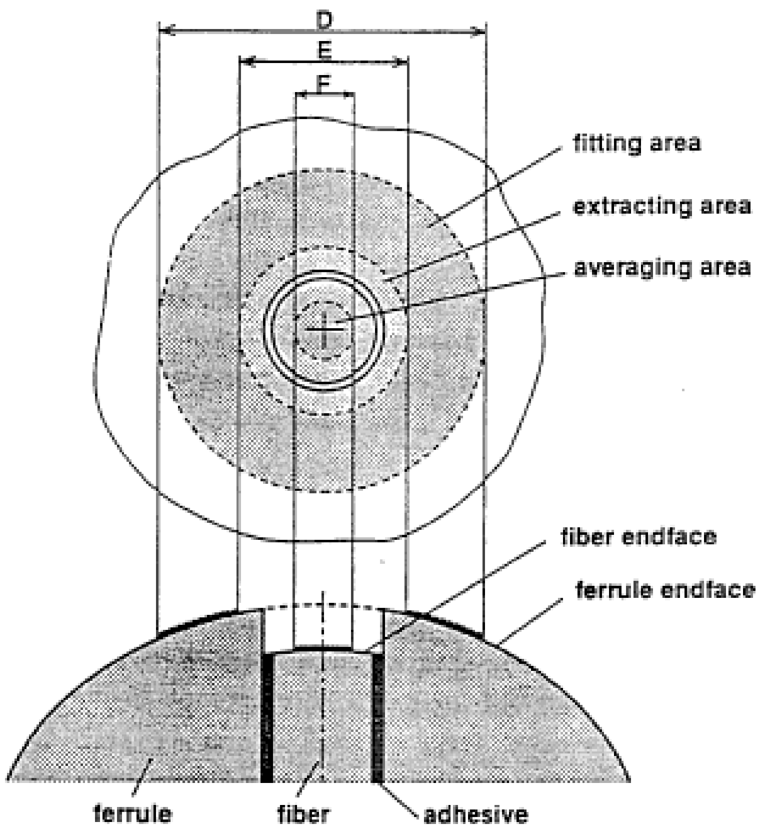


Figure 4 Measurement Areas

A Fitting Area: Centered on the ferrule surface and defined by a circular area having a diameter D with a smaller Extracting Area subtracted from its center. D = 250 microns.

An Extracting Area: Includes the fiber endface region and the adhesive region and is defined by a circle having a diameter E. E=140 microns.

An Averaging Area: This is set on the fiber surface and defined by a circle having a diameter F. F=50 microns.

These three areas shall be centered on the ferrule axis which is essentially coincident with the fiber center.

Note: Measurement areas in Fig. 4 are not to scale. They are for illustration only.

DEFINITIONS

Radius of Curvature:

The radius of curvature is defined as the radius of the best fitting sphere over the defined Fitting Area. This can be calculated using a least squares method to find the best radius. Since this is a spherical measurement, using all available ferrule surface data, it is the most accurate possible representation of the area. Two dimensional methods of calculating the radius are also possible. However, they are inherently less repeatable due to the use of only selected surface data. Therefore, the resulting radius may vary depending on which cross sectional data is used for the calculation. See Fig. 1 for typical values.

Apex Offset:

Measuring the apex offset (offset of the polish from the fiber) requires defining the "high point" or vertex of the polish. Since the fiber itself could be recessed or protruded, the sphericity of the ferrule surface as defined by the Fitting Area is used to calculate the vertex.

The apex offset is defined as the distance from the vertex of the ferrule sphere to the center of the fiber. Interferometry, because of its three dimensional contours, visually shows the vertex as the center of the circular fringes that define the sphere (Fig.5). It is a simple matter to calculate the linear distance from this point to the fiber center. See Fig. 1 for typical values.

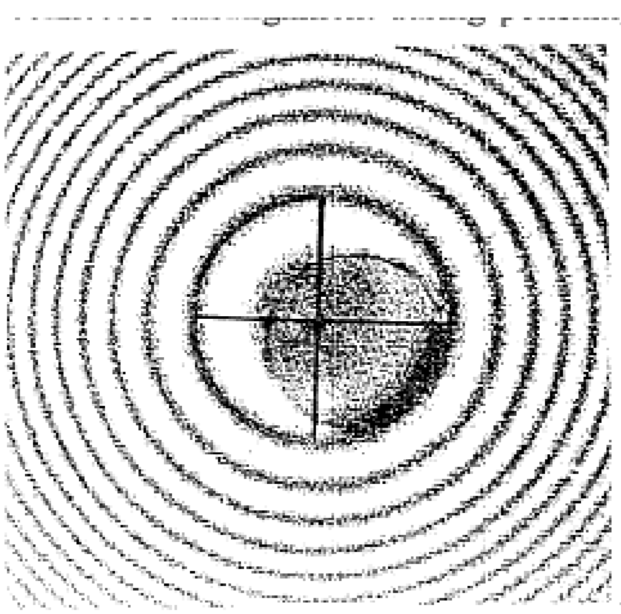


Figure 5 Apex Offset

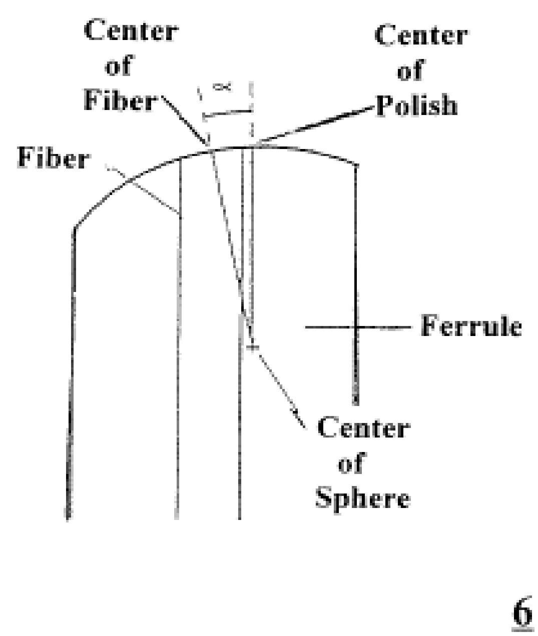


Figure 6 Angular Offset

Offset can also be defined as an angular offset. Angular offset is defined as the angle between the radial line through the high point of the polish and the radial line through the center of the fiber (Fig. 6). Both linear and angular offset can be divided into X and Y components. If the connectors are keyed to control orientation, the manufacturer can use the X and Y data to identify trends related to connector misalignment during polishing

Fiber Height:

There are two suggested ways to define fiber height, Spherical Height and Planar Height[7].

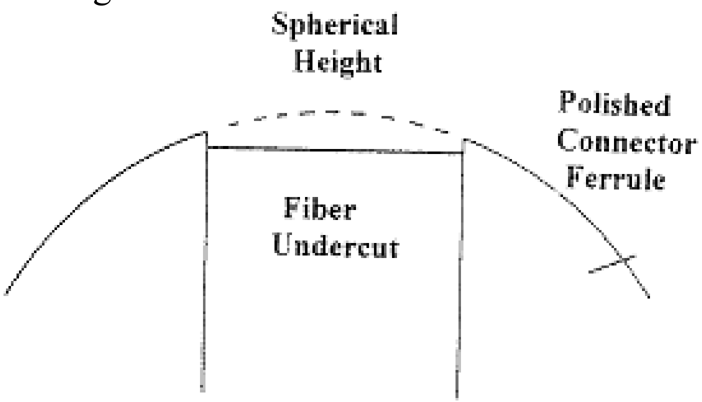


Figure 7 Spherical Height

1. ***Spherical Height*** is useful when the ideal connector endface (ferrule and fiber) is considered to be a continuous sphere. It is defined as the difference in height between the center of the fiber and the theoretical height in the center based on the ferrule radius. See Fig. 1 for typical values.

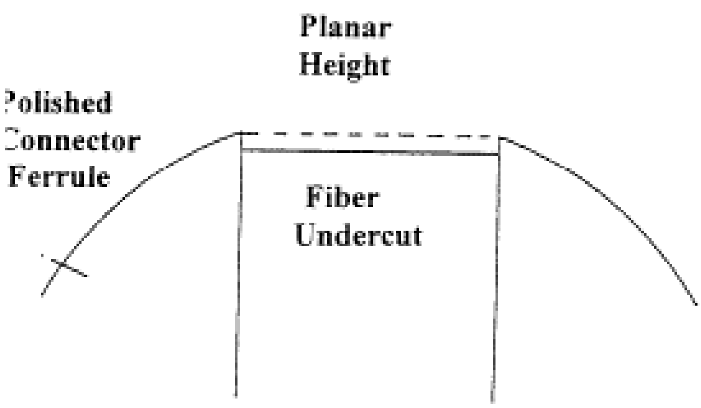


Figure 8 Planar Height

2. ***Planar Height*** is useful when the ideal connector endface is considered to be a flat fiber in the middle of a spherical ferrule. It is defined as the difference in height between the center of the fiber and the height in the center of the theoretical plane formed by connecting the highest points on the ferrule on either side of the fiber.

In summary, the fiber optics industry is improving connector quality by exploring which key, physical parameters need to be measured and the best way to measure them. With the proper definitions and standards for the polish geometries and procedures, manufacturers can provide PC polished connectors with low back reflection that will stand up to the long term demands of today's fiber systems.

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